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EARTH'S LOWERMOST MANTLE BECOMES MORE COMPLICATED

EXTREME RARITY OF LONG-LIVED PEOPLE POST-FLOOD

LIGHT TRAVEL IN THE UNIVERSE

—ABSOLUTE OR RELATIVE MOTION?

HOW DID THE ISRAELITES **CROSS THE RED SEA?**

DOES THE HUMAN HAND HAVE **TOO MANY BONES?**

JOURNAL OF CREATION

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COVER: Artistic impression of light flare in space

IMAGE: © Evelyn Doyle

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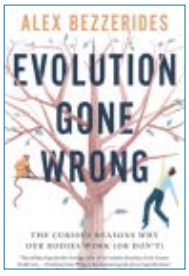

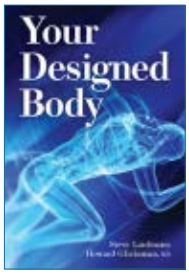

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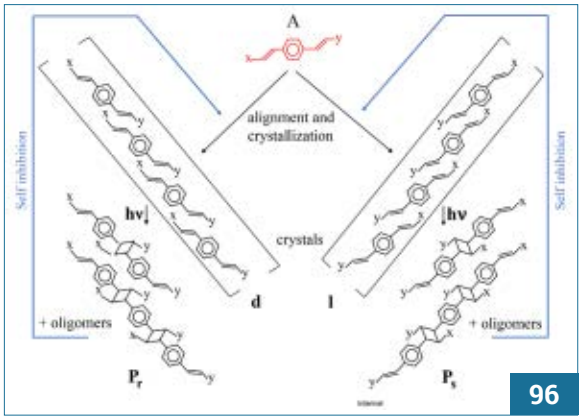

Naturalistic explanations for the origin of proteins from their L-amino acid building blocks (and not their 'D' mirror-image counterparts) are irrelevant and have been discredited.

The formation of asteroids, trans-Neptunian Objects, and comets remains an elusive problem for the Hydroplate Theory.

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ABOUT US

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» The account of origins presented in Genesis is a simple but factual presentation of actual events and therefore provides a reliable framework for scientific research into the question of the origin and history of life, mankind, the earth and the universe.

» Scripture teaches a recent origin for man and the whole creation.

» The great Flood of Genesis was an actual historic event, worldwide (global) in its extent and effect.

» The special creation of Adam (as one man) and Eve (as one woman) and their subsequent fall into sin, is the basis for the necessity of salvation for mankind (and thus for the Gospel of Jesus Christ).

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Surprising ecosystem in northeastern Greenland supports biblical Ice Age

Michael J. Oard

Scientists have developed a new method for discovering which animals inhabited an area. This method analyzes the environmental DNA (eDNA) in the soil from plants and animals that once lived in the region. The method was applied to the Kap København Formation in northeast Greenland, where research has been conducted for nearly 40 years. The area today is a polar desert, home to just a few plants, hares, and musk oxen. Scientists had previously found macrofossils from coniferous boreal forest trees and a rich insect fauna, but they were greatly surprised by what they discovered recently.

Several surprises

Scientists found what they believe to be 2-Ma-old DNA, which pushed back the occurrence of ancient DNA almost 1 Ma.[1] They obviously do not accept discoveries of DNA in dinosaurs.[2,3] Comparing the eDNA to a data bank of DNA from modern plants and animals, the researchers were amazed to find DNA from mastodons, reindeer, rodents, geese, and rabbits that inhabited a forest ecosystem of poplar, spruce, cedar, and yew trees combined with present-day polar vegetation.[4] They identified 102 genera of plants, whereas earlier paleontologists had only identified eight.[5] Some have disputed whether the mastodon DNA is truly from a mastodon or some other elephant.[5]

Such an ecosystem requires much warmer temperatures than today. The present-day average temperature is –17°C. The researchers estimated it would have been 10°C warmer 2 Ma ago, but there are indications that it may have been even warmer, since many of the plant fossils found do not grow on permafrost. No-one predicted such an ecosystem, and there are no modern analogues. One researcher was quoted as saying: "Not in a million years would you expect a mastodon up there."[4]

Mastodons remains are found in forests in the United States but are never found in Greenland. And reindeer supposedly had not evolved by that time, as admitted by paleogeneticist Eske Willerslev: "Reindeers, according to paleontologists, should not have survived; they shouldn't even exist at that time."[4]

Biblical interpretation

Creation scientists do not accept the date of 2 Ma but have no trouble accepting that this DNA would still exist since all of this eDNA is only thousands of years old. Two Ma lies at the outer edge of DNA's theoretical shelf life.[6] We have two choices in determining where the organisms fit into biblical Earth history. First, the organisms could be from the Flood. A great number of warm-climate Cenozoic fossils exist in the polar areas of the Northern Hemisphere. For instance, trees typical of the southeast United States are found with alligators, crocodiles, large tortoises, and lemurs on Ellesmere and Axel Heiberg Islands, and are dated as early Cenozoic.[7–10] However, these fossils indicate a climate that would be too warm for the early Ice Age.[11] For instance, sea surface temperatures would have cooled too rapidly after the Flood to sustain the observed tropical and subtropical paleoflora.

Image: Alice Hunter, Wikimedia / CC BY-SA 4.0

Figure 1. Map of Canada showing the many islands and straits in northern Canada that animals would have to navigate to reach northern Greenland.

Moreover, winters would have been too cold to sustain them. Furthermore, the preserved leaf-litter sequences on Axel Heiberg Island are preserved as well at the bottom of each layer as they are at the top.[12] This indicates rapid deposition during the Flood rather than prolonged exposure afterwards. Therefore, these Cenozoic fossils are from the Flood.

The other option for the Greenland eDNA is that the organisms could be left over from the Ice Age. The oceans would have been warm early in the Ice Age due to the heat produced during the Flood. The Arctic Ocean could have been over 20°C, keeping coastal areas mild by onshore air flow early in the Ice Age.[13] Plants and animals that preferred temperate climates could have lived comfortably for hundreds of years in the far north, especially along the coastal areas of the Arctic Ocean. Considering the eDNA evidence, the organisms from northeast Greenland are typical Ice Age animals, such as reindeer and mastodons. Thus, the evidence from eDNA for northeast Greenland, in contrast with that for Axel Heiberg Island, indicates a post-Flood environment. In other words, the fossils in the Kap København Formation were buried early during the temperate climatic conditions during the post-Flood rapid Ice Age, while the Arctic Ocean was relatively warm.

How did the mammals make it to northern Greenland?

There is the question of how the animals would have been able to migrate to northern Greenland across multiple straits, the last being the Nares Strait between Ellesmere Island and Greenland (figure 1). The large mammals could have swum, especially since the water would have been relatively warm. Mammoths made it to the Channel Islands off the southern California coast by swimming since there was no land bridge.[14,15] Elephants are excellent swimmers: "My research shows that modern elephants are excellent distance swimmers, among the best of all land mammals, and skilled at crossing water-gaps."[16] Or, the animals of northeast Greenland may have been aided by log and vegetation mats left over from the Flood that would have floated for many years on the post-Flood oceans.[11] This transportation would be especially likely for the small mammals.

To be aided by log mats, the animals had to first cross the Bering Land Bridge. This land bridge was more likely exposed early in the Flood when animals could more easily journey through Siberia into Alaska, when winters were mild, not at the end of the Ice Age, when winters were colder than today.[17] Further evidence of this early Ice Age land bridge is the finding of Columbian mammoth fossils at the bottom of Ice Age debris in central British Columbia.[18] These mammoths could only arrive at this location from the ice-free corridor and through the Peace River water gap before the mountain ice caps inundated the lowlands of British Columbia. eDNA evidence of animals on northeast Greenland also adds to the indirect evidence that the Bering Land Bridge existed early, but not late in the Ice Age. Moreover, some log mats would still have existed for transportation. Northern Canada also needed to be warm enough for forests to grow, which need not have been large for them to shed pollen and eDNA and animals to survive in northern Greenland.

Conclusion

Researchers were amazed to find DNA evidence of a temperate ecosystem in the Kap København Formation in northeast Greenland. The most likely explanation is that these fossils were buried during the early part of the post-Flood rapid Ice Age.

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An ape fossil found in South America

Michael J. Oard

Both uniformitarian and creation scientists make deductions based on fossil order in the geological column and on their worldwide distribution. Biogeography analyzes the present animal and plant distributions to explain how they arose. Animal and plant fossils enter into the deductions. We generally know the present distribution of animals and plants, but explanatory difficulties emerge when considering fossil distributions. Surprises still happen that require changes in the ideas of fossil distributions and biogeography. We really do not have a complete knowledge of fossil distributions.[1]

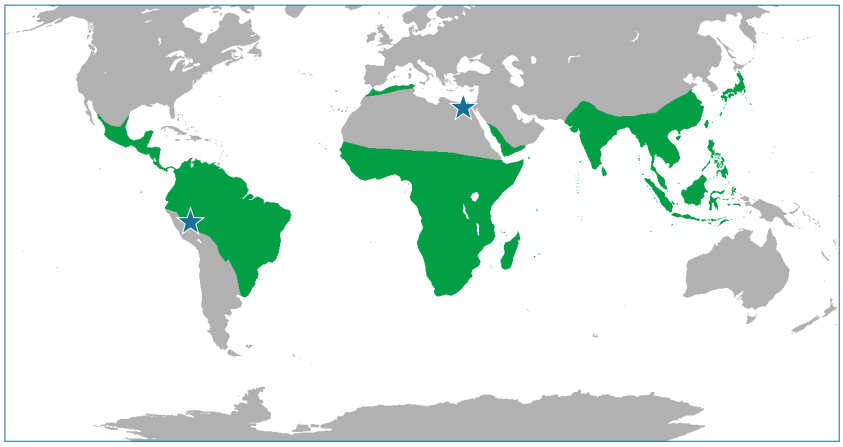

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Figure 1. Range of present-day non-human primates. Locations of recently discovered fossil primates from the family Parapithecidae from eastern Peru and northeast Africa indicated with stars. Although there are no apes in Egypt today, fossil apes are found there.

Northeast African ape fossil now found in western South America

Recently, an ape fossil was discovered in the Paleogene (early Cenozoic) in the Amazon of Peru in South America.[2] Another unidentified ape was also found from the family Parapithecidae, the only other fossil distribution of which is from northeast Africa and Arabia (figure 1). Uniformitarian scientists are then forced to advocate rafting across the Atlantic Ocean over 1,500–2,000 km, the distance between the two continents at that time according to plate tectonics.[3] The ape discoveries were completely unexpected:

> "The discovery of a parapithecid stem anthropoid in the late Paleogene of Peruvian Amazonia is entirely unexpected and provides a notable example of how important paleontological information is for understanding the ephemeral forces that shaped modern biodiversity."[4]

Besides rafting across the Atlantic Ocean, the fossil site is more than 4,000 km from the easternmost point of South America, and the African fossils are far from the Atlantic Ocean. Then how did the apes migrate from northeast Africa to the Atlantic Ocean, catch a raft, and spread 4,000 km to western South America? This suggests to uniformitarian scientists that the animals must have at one time been widely distributed across Africa and South America, but there is no fossil evidence of this.

Noah's Flood implications

The unexpected discoveries highlight the fact that we still do not know precise fossil distributions. More discoveries are expected in the future. Another notable discovery in South America was the finding of a 'platypus-like' monotreme in southern Argentina dated to about 60 Ma.[5] Monotremes were assumed to be denizens of only Australia.

The interpretation of ape fossils depends upon the location of the Flood/post-Flood boundary. We do not know whether these ape fossils were deposited during the Flood or rafted after the Flood after spreading from the 'Mountains of Ararat'. If post-Flood, we should find the type of ape fossil between northeast Africa and western South America, and we do not. So, these ape fossils are likely to have been laid down in the Flood. But large natural rafts could have carried monkeys and apes found in South America today from Africa post-Flood. The rafts in the Creation/Flood Model are much larger and more capable of carrying animals over oceans than any that uniformitarian scientists could muster from vegetation ripped up by storms.[6,7]

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Rocks don't lie—battling worldviews

Carl R. Froede, Jr, and A. Jerry Akridge

Naturalists often confuse their worldview invoking eons of geologic time with empirical science. Many are so indoctrinated with the concept of deep time they fail to notice conflicting evidence. A recent article, published in the monthly open-access *GSA Today*,[1] demonstrates this problem. The authors state:

> "Astronomy and geology require contemplation of time scales and length scales far outside those of human experience. Granitic plutons are intruded and crystallized at depths ranging from a few kilometers to tens of kilometers, over durations of 10^{-5} [100,000] to 10^{-7} [10,000,000] years, at temperatures comparable to the melting temperature of gold, from magmas at least 10,000,000 times more viscous than water. Human experience is not relevant to these conditions and can be highly misleading."[2]

This statement assumes the Genesis Flood never occurred and humans did not exist on Earth when granite formed in the subsurface or possibly later became exposed through the erosion of the overburden. Is this statement a matter of empirical science or the projection of a naturalistic worldview?

Flood-formed granites

The formation of granite and granite landforms has been studied by many young-earth creationists (figure 1).[3–11] Creationist research indicates that water-enriched granitic melts can form, move upward through the crust, and crystallize in days to weeks. This occurred during the Creation Week (most likely Day 3[12]) and also during the Flood—two periods of Earth's past when geologic intense activity is expected based on the outline in Genesis.

Figure 1. The Stone Mountain Granite monadnock (east of Atlanta, Georgia, USA) rises approximately 270 m above the surrounding hills.[13] It is proposed that the granitic melt rapidly formed and was intruded into overlying metamorphic overburden where it quickly crystallized. In places, the metamorphic overburden was subsequently eroded away, leaving the granite exposed. All of this occurred during the Genesis Flood.[14]

The rapid creation, mobilization, and crystallization of granite would have been enhanced by aqueous conditions associated with the breaking up of the fountains of the deep with the onset of the Flood. Entrained water within the rapidly heating rocks and sediments would have decreased the melting temperature, increasing melt mobility, and enhancing its rapid crystallization.

In some instances, remaining latent heat within subsurface granitic melts/crystallized masses generated during the Flood would have allowed them to continue as heat sources up to the present age timeframe (figure 2). Today, hot springs and other geothermal areas may indicate these features.

The biblical outline of Earth's history allows for this conceptualization and provides a framework to test our worldview relative to the development of granite.

The naturalistic perspective

While not within a period of time compatible with the Bible, some naturalists acknowledge the rapid formation, ascension, and crystallization of granitic melts is possible over short periods of time (<100,000 years).[15,16] However, with little water in the slowly forming melt, naturalists envision the entire granitic formation-to-crystallization process would extend over millions of years due to the slow-moving tectonic processes essential in melt generation, movement, and eventual crystallization. During this lengthy time interval, most of the water / hydrothermal fluids within the subsurface rocks and sediments would be driven off, thereby reducing its effectiveness in generating a more mobile granite melt at lower temperatures. The naturalistic worldview imposes limits in both the conceptualization of granitic development and the empirical methods used to test its ideas.

Interestingly, pegmatites that cross-cut granites (figure 3) are postulated by naturalists as having formed and crystallized rapidly—"in days to months, not in thousands to millions of years as previously believed."[17] This view is not isolated, as many other petrologists invoke days to months for the formation and development of pegmatites.[18–23] There is no current naturalistic model that emplaces pegmatites in a water-depleted environment.[24] They are always associated with water-enriched feldspars, quartz, and minor trace elements within a slowly crystallizing granitic melt. Missing is the reasoning to minimize water and other hydrothermal fluids from the original granitic melt.

Battling worldviews

Understanding the conceptual geologic history of granites demonstrates the differences in worldviews between naturalists and Bible-supporting young-earth creationists. This is not a battle over empirical science, but rather over the framework of our ideas (i.e. philosophy/theology). These foundational assumptions drive the investigation of geologic features like granites. Oftentimes these foundational assumptions impede scientific progress because they limit possibilities in designing appropriate models for further testing.

Conclusions

Ultimately, through scientific testing, a dominant theory for the origin, movement, emplacement, and crystallization of granite will emerge. The naturalistic worldview rejects everything but the physical universe and its many geologic concepts operating over millions of years. Most young-earth creationists accept both the physical and the supernatural—as conveyed through Scripture—in the scientific investigation of geologic features found across Earth.

The Bible is our only source of absolute Truth and the geologic history it outlines will be supported by empirical testing. Regarding granitic development, naturalists will eventually discover what young-earth creationists have already started to demonstrate, that a catastrophic model for granitic development is defensible and scientifically consistent with the biblical history of Earth.

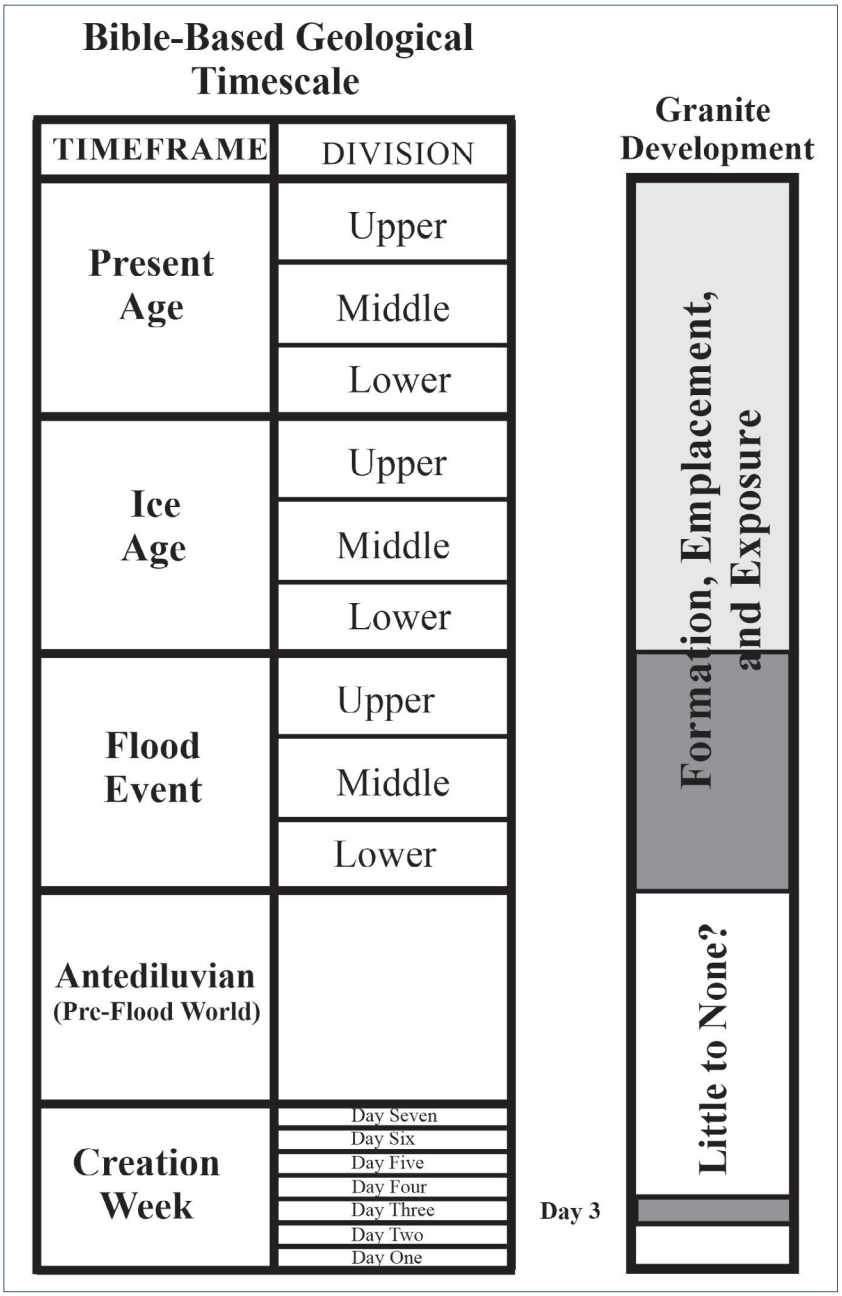

Figure 2. A general understanding of granitic development in the geologic history of Earth can be contemplated based on the Genesis record. The darker shading indicates possible periods of abundant global granitic development. However, granitic generation, emplacement, and crystallization on Day 3 of the Creation Week may be beyond empirical determination. Granites derived at the onset of the Flood could prove easier to scientifically document.

Figure 3. An aplite-pegmatite dike exposed in the Stone Mountain Granite. Naturalists contend that water-enriched pockets of feldspars and quartz within the granitic melt can very rapidly form pegmatites like this one. These features can quickly crystallize in hours or days. The width of the dike is approximately 33 cm.

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Does the human hand have too many bones? Another claim by Nathan Lents proven false

Jerry Bergman

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Figure 1. Bones of the hand focusing on the carpal bones.

Nathan H. Lents' argument for evolution includes his claims that the human body is poorly designed. He not only argues that evolution explains the poor design but that this fact disproves the intelligent-creator belief. Virtually all of his arguments have been decisively refuted[1] but he has, in his latest book, come up with a few novel claims. One claim he makes that I have looked into is that humans have "way too many bones" in our body.[2] He explains this problem as being due to the fact that, as we evolved, certain structures were no longer needed, but removing them was too much of a problem. He then trots out one of the most effective arguments creationists use:

> "For a [human] body to take shape, thousands of genes must be activated and deactivated in a precise order, perfectly coordinated in time and space. When a bone, for example, is no longer needed, deleting it is not as easy as flipping a switch. Hundreds—maybe thousands—of switches must be flipped, *and* they must be flipped in such a way as to not screw up the thousands of other structures that are also built with those same genes. Remember too, that natural selection flips these switches randomly, like a chimpanzee at a typewriter [emphasis in original]."[2]

After acknowledging the good design of the human hand, he then claims:

> "… it is way more complicated than it needs to be. … the wrist bones are helpful, but they don't really do anything individually … . No sane engineer would design a joint with so many individual moving parts. It clutters up the space and restricts the range of motion."[3]

Here he is referring to the eight carpal bones in the wrist (see figure 1). His 'fix' is, if there was an intelligent creator, He would have used one, or at most two, carpal bones, not eight. Lents then adds that the same problem is also true of the human foot and even our ankle, which he writes "contains seven bones, most of them pointless. … the ankle is a hodgepodge of parts that can do nothing except malfunction."[4] In contrast to Lents' claim, the ankle actually has only four bones, not seven as he claims. They are the calcaneus, the tibia, the fibula, and the talus. The other three bones that Lents refers to as being part of the ankle are actually part of the midfoot.

The most obvious response to this claim is that the carpal bones' design is what allows the hand, especially the thumb, to achieve its enormous set of functions as described below. This conclusion has been confirmed by studies of the carpal bones.[5] The movement in those eight wrist bones is what allows the all-important thumb flexibility. The lower primates do not have the same set of carpal bones as humans do, hence they do not have the hand capabilities that we do. This distinction is important because "The hand is one of the most distinctive traits of humankind and one of our main sources of interaction with the environment."[6]

The fact is, there is "no work of art, no more wonderfully engineered contraption, than the simple human hand. It … is a wonder of design, and represents the work, talent and mind of a wondrous designer."[7] The hand's very delicate and complex structure gives its muscles and joints a great range of movement and precision.[8] Its 27 individual bones, 25 joints and 30 muscles allow it to produce 58 distinctly different motions.

Advantages of the eight-bone design

To achieve this and other hand feats requires the function of a large portion of the brain, as shown in the homunculus (figure 2). The superior dexterity of the human hand, especially the opposable thumb (a thumb able to touch the tip of any other finger), is a unique feature of humans. No other primate, or even mammal, can achieve feats even close to this ability. As hand surgeon Dr Napier explains, the hand's

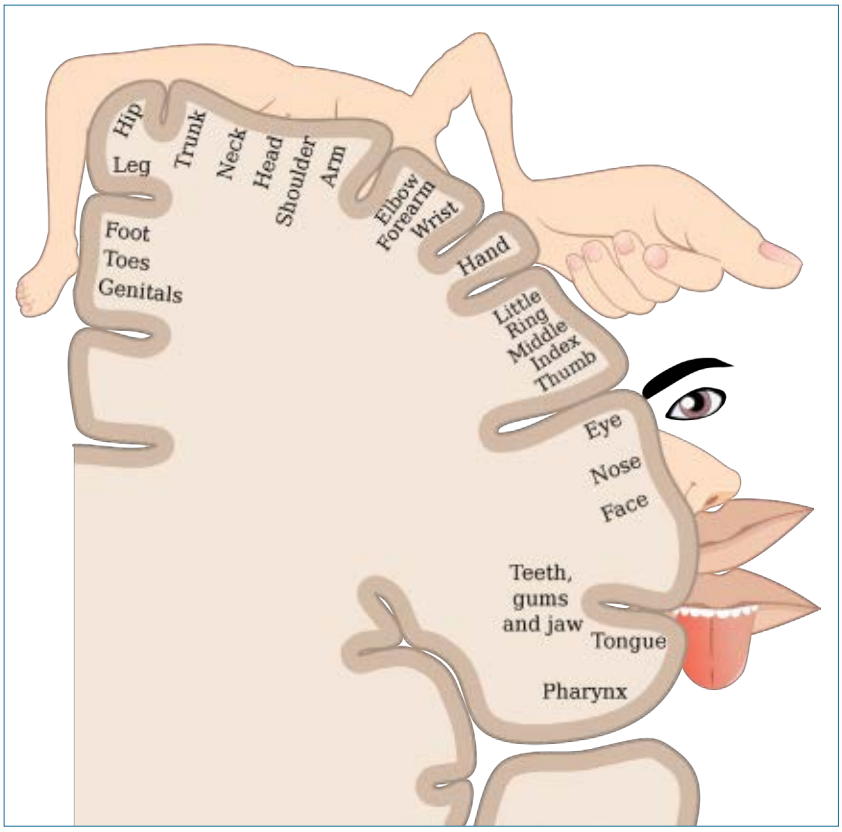

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Figure 2. Homunculus cartoon showing the relative brain usage for the various parts of the body. Note that the hand and vocalization dominate space in the brain.

"acute sensitivity, precision, subtlety, and expressiveness clearly distinguish man from all of the other animals."[9]

The existing design of the hand is able to achieve almost superhuman speeds and still maintain precision control. Polish pianist Ignacy Jan Paderewski was filmed, revealing that while playing one of his own compositions he hit 120 notes a second using both hands. Using one hand playing another one of his own compositions he hit 20 notes a second with each finger.[10] As a trained pianist, he has achieved a proficiency far greater than that of the average person, but this shows what the hand is capable of, given practice and dedication.

The hand and its five fingers are estimated to assume a total of 300 million useful positions. One example of the hand's versatility is illustrated by the close to 10,000 American Sign Language hand signals for the deaf.[11] Each finger plays an important role in the hand's achievements. Likewise, each bone in the hand, including the carpal bones, has an important role to play in the hand's flexibility. Focusing on the hand's movements while doing simple everyday tasks, such as buttoning a shirt collar, illustrates this ability.

In addition, the hands have about five million sense organs that enable enough control to squeeze a lemon and yet pick up an egg without shattering it. This information allows the brain to finely control the pressure we use to achieve different tasks. Research on the blind has determined that their senses have become fine-tuned to the degree that they are able to use their hands to detect differences in paper thickness as small as a few ten-thousandths of an inch.

Anatomist's description of the wrist bones' function

The eight wrist bones are divided into proximal and distal rows (figure 1). The proximal carpal row consists of the scaphoid, lunate, triquetrum, and pisiform. The distal row comprises the trapezium, trapezoid, capitate, and hamate.

> "These [carpal] bones make up most of the skeletal framework of the wrist and allow different neurovascular structures and tendons that enter the wrist to reach certain muscle groups and bony structures, respectively and provide the innervation and blood supply necessary for them to function."[12]

The fact is that the "motion of the eight carpal bones is extremely complex" partly because of their multiplanar rotations and translations, which allow the enormous complexity of the hand and thumb movement.[13] Severe osteoarthritis of the carpal bones impedes normal hand movements, especially the thumb, supporting the conclusion that the existing eight-bone design is required to allow normal hand movement, especially the thumb.[14]

In short, these bones are not useless but every "carpal bone has its own unique features that contribute to a specific function in the wrist."[12] Research of the relative contributions of the eight wrist bones has determined that

> "The scaphoid, lunate, and capitate move synergistically throughout planar wrist motion. The scaphoid and lunate contributed at a greater degree during flexion, suggesting that the radiocarpal joint plays a more critical role in wrist flexion."[15]

The importance of the wrist is illustrated by the fact that the fingers themselves contain no muscles. Our fingers are individually moved by tendons *that are threaded through the wrist* and attached to muscles all the way up into the forearm. This design

works extremely well to achieve precise control and sensitivity.

How the carpal system functions

The details of the carpal system illustrate the many functions the system serves. The scaphoid surface is covered by articular cartilage, which allows it to bridge the joint located between the two rows of carpal bones. The triquetrum articulates with the pisiform, lunate, and hamate bones. The pisiform, however, articulates with the triquetrum on its dorsal surface and functions as an attachment site for various tendons and ligaments. The capitate, the largest and most central carpal bone, articulates with several bones and attaches to several intercarpal ligaments. Lastly, the hamate serves to protect the ulnar artery and nerve within Guyon's canal and provides attachments to several ligaments.

This complex anatomical design contributes to the hand's ability to grasp objects with precision. The carpal bones' arrangement provides support and protection to the finger flexor tendons and the median nerve. The scaphoid and trapezium both have prominent tubercles projecting anteriorly that provide a supporting base for the thumb to allow it to oppose the rest of the hand, and thus enhance the hand's ability to grasp objects. Our thumb is the most important digit, accounting for 40% of the hand's capabilities. It is a combination of power tool and nimble manipulator.[11] The evidence is clear; a single carpal bone, as Lents argues is desirable, would not only be significantly inferior, but would greatly reduce the hand's ability to grasp, largely negate the thumb's critical opposition role, and cause the hand to behave more like a foot as occurs in certain monkeys.

Evolution of the hand

A comparison of the higher apes and man shows the gorilla 'hand' is closer to the human hand than it is to the chimpanzee 'hand', yet the design of both the gorilla and chimp 'hands' allows them to perform their major function as, in effect, feet in knucklewalking, yet also function to grasp a banana and a vine.[16] The lack of evidence for the link to the presumed common ancestor of chimps and humans produces a situation where "We are now staring at a maddeningly blank page in our hand [evolution] story".[17] Nonetheless, evolutionists accept the belief that humans and chimps evolved from a common ancestor and bemoan the fact that fossils linking human with chimp hands "are even rarer than those of skulls."[18] This is a problem, Wilson states, that would be solved if we kept looking in the fossil record.[18] Unfortunately for evolutionists, we have been looking for over 150 years now without any evidence of a viable fossil link from chimps to humans. Wilson adds that "evolutionary theorists rightly caution us to curb our passion for finding purpose in evolution".[19] Nonetheless, he adds that the hand, and especially its thumb, "is an astonishing example of versatility realized through structure". This is of course a perfect example of purpose.[19]

Summary

The literature has been shown to document the fact that Nathan Lents' claim of poor design of the hand is not only wrong, but egregiously so. Fusing the eight bones of the wrist into one or two bones would severely impede the range of functions of the hand currently existing in healthy humans. The existing design is vastly superior to the 'fix' Lents proposes, which would reduce the hand's flexibility. In short, the human hand is a marvel of biomechanics, a triumph of complex engineering.[20] In fact, the hand was for decades viewed "as proof of the existence of God."[21] This claim was very effectively demonstrated in surgeon Sir Charles Bell's book on the hand.[22]

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Lowermost mantle becomes more complicated

Michael J. Oard

The lower mantle resides at a depth between 660 km to nearly 2,900 km inside the earth and consists of 56% of Earth's total volume. It is believed to consist of three minerals: bridgmanite, ($(Mg,Fe)SiO_3$), ferropericlase ($(CaMg)O$); and calcium-silicate perovskite ($CaSiO_3$). Bridgmanite is believed to be the major component.[1]

Importance of lower mantle to the Flood

The properties of the lower mantle are important since models of its viscosity, temperature, density, and composition would impact several aspects of any Flood model, such as vertical tectonics, catastrophic plate tectonics (CPT), estimates of seismic velocities, seismic tomography interpretations, and others. Some of the issues involve the interpretations of what are called Large Low Shear Velocity Provinces (LLSVPs) and ultralow-velocity zones (ULVZs).

LLSVPs and ULVZs

LLSVPs consist of two regions of low shear wave velocity in the lowermost mantle as detected by seismic tomography (figure 1). They are located under Africa and the western Atlantic (named Tuzo) and over much of the equatorial Pacific Ocean (named Jason). LLSVPs are surrounded by regions of higher seismic velocity. They cover about 30% of the lowermost mantle above the core-mantle boundary (CMB) and are believed to extend upward around 1,000 km.[2] They have been consistently detected for many years by numerous tomographic observations, so they are very likely real features. It is interesting that the LLSVPs mostly straddle the equator and are antipodal to each other. Seismic S-wave (shear-wave) velocities are 2% less and P-wave (primary wave) velocities are 0.5% less, respectively, than the average of lowermost mantle velocities[2] with lateral and vertical heterogenicity.

Seismic waves are affected by both pressure and temperature differences. If seismic velocity is entirely caused by temperature differences, every S-velocity decrease of 1% equates to a temperature increase of 200°C.[2] And if the LLSVPs are entirely thermal, they would be buoyant, which is one reason why secular scientists believe that the LLSVPs are mostly or entirely chemical differences providing higher density.[3,4] Thus, LLSVPs are believed to have remained above the CMB for hundreds of millions of years.

However, in the CPT model, they may be hotter lower mantle blobs pushed to these locations by cold subduction slabs 4,500 years ago during the Flood.[5] Then, there may not have been enough time for the hotter blobs to rise appreciably, but they still could have been the cause of 'mantle plumes' that would explain 'hot spots'.

However, the cause and properties of LLSVPs are still unknown.[6] The bulk sound velocity is probably 0.5–1.0% higher in LLSVPs than average,[7] which suggests that the reduced seismic velocities are not all due to higher temperature.

ULVZs are much smaller than LLSVPs in area, believed to be only 5–25 km thick, and reside on top of the CMB.[8] They have S-wave and P-wave reductions of 5–50% and 5–25%, respectively, giving much lower wave velocities than LLSVPs! Their distribution is patchy on the CMB and are generally associated with LLSVPs (figure 1).[9] The cause of ULVZs is unknown, but suggestions include partial melts, a different composition of lowermost mantle minerals, strong heating from the core, ultra-dense subduction remnants, etc.[6]

Secular scientists suggest LLSVPs and ULVZs could be primordial, caused by differences in the precise chemistry of mantle minerals, caused by the sinking of a 'magma ocean', caused by heat from the core, or as a result of subduction.

A new mineral phase discovered in a super-deep diamond

Researchers had previously assumed that calcium-silicate perovskite, which has been investigated at room temperature and mantle pressures, was in its tetragonal configuration in the lower mantle. It shows great strength against deformation.[10] Just recently, researchers discovered a new phase of calcium-silicate perovskite in a 'super-deep' diamond from South Africa that they estimate formed 200–1,000 km deep in the earth.[11] Such diamonds sometimes also contain other lower mantle minerals. After forming at depth, these diamonds are carried rapidly to the surface in narrow explosive diatremes, also called kimberlite pipes.

The particular structure of calcium-silicate perovskite in the diamond is cubic and is considered a new lower mantle mineral. It is called davemaoite, named after Ho-kwang 'Dave' Mao, a prominent Chinese researcher who made many pioneering discoveries

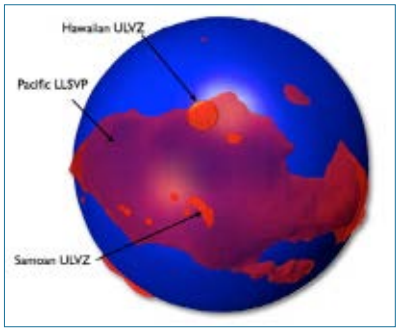

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Figure 1. Graphic of structures on the core of the earth (blue). The Pacific LLSVP is shown in red with the smaller, thinner, ULVZs shown in bright red.

in high-pressure geophysics and geochemistry. The cubic form is highly unstable at the earth's surface, which is why it was previously unknown. Davemaoite is likely the mineral that represents calcium-silicate perovskite throughout the lower mantle and would make up 5–7% of the lower mantle.[12]

Davemaoite surprisingly 'soft'

The properties of davemaoite were discovered when researchers put calcium-silicate perovskite in a diamond anvil press under a pressure equivalent to a 1,200 km depth and heated it to 1,150°K.[10,13] They not only formed the cubic structure, but also were able to deform the crystal and analyze its properties. The bulk modulus (its resistance to compression) and viscosity of davemaoite turned out to be significantly lower than bridgmanite and ferropericlase. The degree of 'softness' depended upon the precise composition, since davemaoite can have minor component impurities of other elements as well as the radioactive elements uranium, thorium, and potassium.[14]

The possible significance of davemaoite

Because of the relative softness of davemaoite, researchers hypothesize that it may explain low seismic velocities in the uppermost lower mantle, as well as other properties of LLSVPs and ULVZs.[13,14] They also consider that the mineral may have a role in the subduction process, including the separation of the crust and upper mantle lithosphere subducted into the lower mantle.[13] This separation is believed to occur because the oceanic crust becomes denser due to more significant phase changes than those taking place in the subducted uppermost mantle. They suggest that the crust becomes the denser LLSVPs and/or ULVZs and the uppermost mantle remains as the high seismic velocity regions surrounding the LLSVPs. However, the subducted slab is only 100 km thick to begin with, making thick LLSVPs and ULVSs still difficult to explain.

Davemaoite also provides evidence that recycled ocean crust may partially explain the sometimes-perplexing geochemical diversity of ocean island basalts.[13] However, other scientists point out that the ocean crust is only 6–10 km thick of which only 23% is believed to transform to davemaoite.[11] This is way too small a volume for subducted slabs to explain the huge volume of LLSVPs, although it may explain the small volume of ULVZs.[10]

Many variables associated with the lowermost mantle

Much of what is believed about the lowermost mantle is speculative and the discovery of davemaoite adds to that. The problem is that the exact chemical makeup of mantle minerals is quite variable and depends on factors like the heat flow across the CMB, the amount of iron, the electronic configuration of iron that changes with mantle depth, whether the iron is in the ferrous or ferric ionic state, the amount of aluminum and other elements, the existence of a unique phase change to post-perovskite, etc.[1,6,15–17] Such variables can have large effects on viscosity, density, thermal conductivity, seismic wave velocities, and other properties. For instance, if the amount of Al_2O_3 increases 10% in the mantle, it would account for the entire 2% decrease in S-velocity in LLSVPs.[2] Thus, it is still unknown whether the LLSVPs and ULVZs represent temperature changes, compositional changes, a little water,[18] melt, or combinations of any two or more.

Flood implications

Davemoaite and other lower mantle mineral characteristics have several possible Flood model implications. Davemaoite could relate to the dynamics of convergent plate margins.[13] Mantle viscosity is likely much lower than secular scientists assume, which would allow more rapid vertical and/or horizontal tectonics in a Flood model. Both the upper mantle,[19] and now locally the lower mantle, can have much lower viscosity than expected. Davemaoite could also possibly explain low seismic velocity zones in the uppermost lower mantle, as well as the LLSVPs and ULVZs, as at least partly due to composition.[13] Radioactive elements have been assumed to exist predominantly in continental crust and the upper mantle, but they could also exist in davemaoite in the deep mantle. This could have implications for accelerated radiometric decay in the mantle.

The many variables associated with mantle need to be understood better in any secular or Flood model. The fact that the higher velocity zones at the edges of LLSVPs do not line up with presently active subduction zones is an issue that needs better explanation by the advocates for CPT. This is why the high velocity zones are said to be due to 'ancient subduction zones'.[20] But the question is, just how ancient? Creation geophysicists would argue these may have formed just 4,500 years ago. And it is possible they formed early in the Flood year in subduction zones that are presently inactive. More research on this topic is still needed.

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Carbonyl sulfide–mediated prebiotic formation of peptides: irrelevant for origin of life purposes

Royal Truman

On 19 May 2023, Christian Professor James Tour and Mr Dave Farina, a prominent atheist and YouTuber, held a debate at Rice University on the topic, "Are we clueless about the origin of life?"[1] The event has drawn considerable attention on the internet since Farina, who goes by 'Prof. Dave', has exploited a multi-million market of followers who delight in abusing Intelligent Design and creation science personnel in a trademark acrimonious manner that fails to address the science.

During the debate, Farina constantly alleged there was 'tons of research' supporting his contentions. This was followed up within hours by an attendee at the debate who posted a YouTube video on a paper by Orgel and Ghadari from 2004.[2,3]

This video, titled *Debunking James Tour on the Origin of Life*, has been widely linked to other YouTube channels including by Farina. Many science novices promptly began joyfully heaping triumphant abuse in the comment sections on Professor Tour, safe in the knowledge that he had no possibility of responding to each pellet from all the shotgun salvos aimed at him.

However, in the referenced paper, Leman, Orgel and Ghadiri did not claim that their experiments reflected a prebiotic relevant scenario, instead writing cautiously about carbonyl sulfide (COS):

> "We speculated that COS might have played a more general role as a condensing agent in prebiotic chemistry."[2]

Professor Tour sets the trap.

During the debate, Tour repeatedly offered his partner a piece of chalk and asked him to "show the chemistry". He also stated, repeatedly, that Farina should stop quoting hyped-up titles and abstracts and needed to analyze what was done experimentally.

Steve Grayson accepted the first request in a YouTube video.[3] By providing a reference with the chemistry we can now engage in some real scientific discussion. That was the first mistake. Professor Tour's second piece of advice, to analyze what was done experimentally, was overlooked by Grayson, who otherwise has posted some interesting videos on non-scientific topics.[3] The experiments performed were not even mentioned in the video, far less discussed for prebiotic plausibility.

Grayson has engaged in several online debates and seems like a very reasonable and fair person so I will now clarify for him and others what they must not overlook.

It is instructive to review the actual experiments since a recurrent principle is revealed. What we read in the abiogenesis chemistry literature has nothing to do with abiogenesis *research*. It is merely laboratory chemistry, optimized to obtain the wished for results.

What does this claim mean? The goal of the abiogenesis community is to find a natural explanation for how cellular life arose through natural processes. So, what is being *researched*? The chemistry of ancient sedimentary rocks? Or is cellular biochemistry being analyzed in an attempt to work backwards? Certainly not. Organic chemistry specialists are applying advanced knowledge of

how various chemical products could be derived in a laboratory, investing considerable effort to optimize the conditions in order to get the intended result. At most, there are sometimes some lame, unsubstantiated *post facto* claims for why their work might be relevant for origin of life (OoL) purposes.

We have no issue with the laboratory chemistry. Where we take issue is with the *a priori* and clearly absurd claims that some particular OoL problem has been thereby resolved. In a scientific discussion, everyone should object to this.

The experiment

Pure L-phenylalanine amino acid was reacted with pure carbonyl sulfide (COS), leading to an intramolecular cyclization intermediate α-amino acid *N*-carboxyanhydride (NCA). This then reacted with a second L-phenylalanine to produce a dipeptide in 6.8% yield, as shown in figure 1.

During the debate, Tour had emphasized that the amino acids form zwitterions in aqueous solutions having a very low free energy, making them unreactive. An audience participant had asked Farina if any of the papers he referred to included amino acids which had not been derivatized to prevent forming zwitterions. Farina assured her this was so. This answer was obviously nonsense, and, needless to say, we also see that molecule 2 in figure 1 is not a free amino acid.

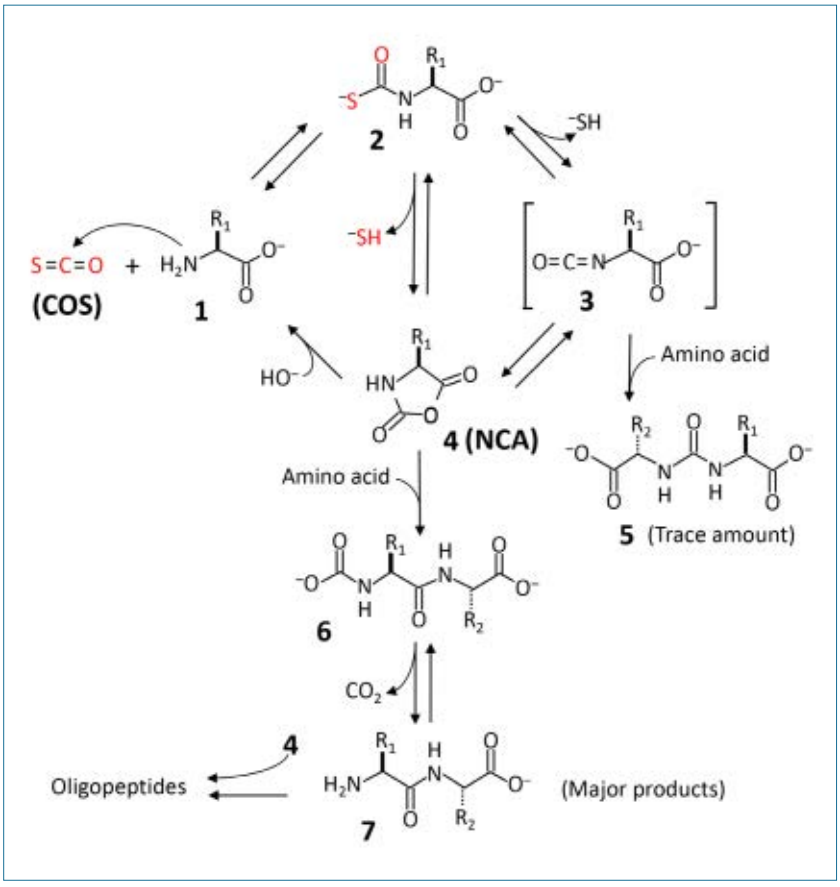

Figure 1. Reaction scheme to produce a dipeptide (after Leman *et al.*[2])

The experiment is irrelevant for OoL purposes.

The following facts show why the reported work does not demonstrate how large polypeptides could have naturally formed in water.

1. In volcanic plumes, COS is a trace gas present in a ratio of 1000−10,000:1 CO_2:COS.[4] COS has a lifetime in the atmosphere of about around 7 years and is currently found in the range 0.51−0.53 parts per billion volume ratio (ppbv).[5] However, this includes all the emissions from chemical processes and the output from plant material. Amino acids like phenylalanine, the companion reactant, are not released by volcanos. OoL specialist Bada estimated that the maximum concentration of amino acids in ancient oceans would have been only about 10^{-8} g/l, which corresponds to about 10^{-10} M.[6]
2. Furthermore, phenylalanine and COS must both be co-located to react and form the intermediate NCA. (The authors did not explain why phenylalanine was selected, and no results for other amino acids were provided.)
3. Therefore, to obtain NCA in a laboratory, the chemists used a COS concentration of 400×10^{-3} M and 50×10^{-6} M for phenylalanine—artificial and impossible enhancements of ~100,000 times![2] For prebiotic modelling purposes that is absurd, especially when we reflect a little deeper.
4. COS, a *gas*, reacts quickly with water to form hydrogen sulfide (H_2S) and carbon dioxide (CO_2).[7] Therefore, the concentrations actually dissolved in a huge prebiotic ocean would have been unmeasurably small. So how did the chemists resolve this problem?
   First, the experiments were performed in a 25-ml Schlenk tube, preventing the reactants from diffusing away.
   Then, *pure COS gas was forced (bubbled) into the reaction mixture!* Right next to the extremely pure, concentrated phenylalanine. What does this have to do with prebiotic chemistry? Nothing! Furthermore, the reported experiment used 8 times more moles of COS than phenylalanine, to optimize the outcome (at least for the outcome they sought).

5. The high concentrations were also necessary so that the intermediate NCA formed would be forced to react with a second phenylalanine.
6. There is another reason why the absurdly high concentration of reactants was necessary: the key intermediate, *NCA, is unstable in water with a half-life of only ~10 hours* in their setup.[2] Under realistic abiotic conditions, NCA would essentially never have encountered and reacted with another phenylalanine. Especially when we take pH into account.
7. Furthermore, volcanic vapours are acidic. For example, detailed studies on plume from the Erebus volcano identified the very strong acids HCl, HF, HNO_3 (>0.03 ppbv), and H_2SO_4 (~0.4 pptv).[8] Therefore, to prevent the destruction of COS and NCA the researchers deliberately worked under very *basic* conditions (initial pH = 9.6). To achieve this a CHES (2- (cyclohexylamino) ethane sulfonic acid) buffer was used, not just irrelevant for prebiotic 'research' but yet another outrageous artifice for OoL proponents to ignore.
   Figure S2 of the Supporting Online Material shows that lowering the pH to just 7.7 decreased the yield of dipeptide by a factor of about 15 to almost 0%! In fact, a higher pH of 10.5 also led to a comparable drop in dipeptide yield suggesting a narrow, required pH range—well outside of that which the alleged volcanic condensate would have.
   This illustrates *the considerable effort invested by the researchers to find the ideal laboratory conditions*, and the results from these experiments were then published.
8. Destruction by acid catalysis cannot simply be ignored. The authors wrote:
   "Because the gas hydrolyzes rapidly on a geological time scale, it is unlikely to have accumulated to a high concentration in the atmosphere. Thus, if COS was important in prebiotic chemistry, it is likely to have functioned *in localized regions close to its volcanic sources*."[2]
   But close to its volcanic sources would mean next to all the destructive acid from the volcanos. A pH of ~9.6 is absurd for OoL purposes. The authors did not report what the half-life of NCA would be at, for example, a pH < 5.
   Incidentally, Grayson also claims that hydrothermal vents would have been a suitable environment for origin of life purposes, such as during a debate on May 25, 2023.[9] However, at a lower temperature of c. 25°C (to minimize the destructive hydrolysis of peptide bonds) hydrothermal fluids have values of pH ≈ 4.7 – 5.4.[10,11]
9. After all the considerable, highly intelligent optimizations had been applied, a meager dipeptide yield of 6.8% was obtained. Lowering both reactant concentrations by many, many orders of magnitude would show that any peptide formed would be too dilute to measure in an ocean, especially since it would hydrolyze much faster than new peptides could form.
   Furthermore, and most unfortunately for evolutionists, a vast number of polypeptides >100 residues would be needed for biogenesis purposes, not simple dipeptides. The fact that these would also racemize was also not mentioned.[12]
10. The researchers meticulously excluded all the other molecules (which would have been present in high concentrations), which would have reacted with COS and NCA, hindering dipeptide formation.

Conclusion

Another chemical laboratory pathway was described to produce a dipeptide after derivatizing the reactant amino acid. Enough laboratory methods to accomplish this are already known which produce higher than 6.8% yield. The described conditions have no relevance to a putative prebiotic world and no effort was made to adjust the parameters to permit extrapolations to calculate realistic dipeptide concentrations or reaction times. Both the intermediate NCA and dipeptide would have hydrolyzed much faster than new dipeptide could have formed.

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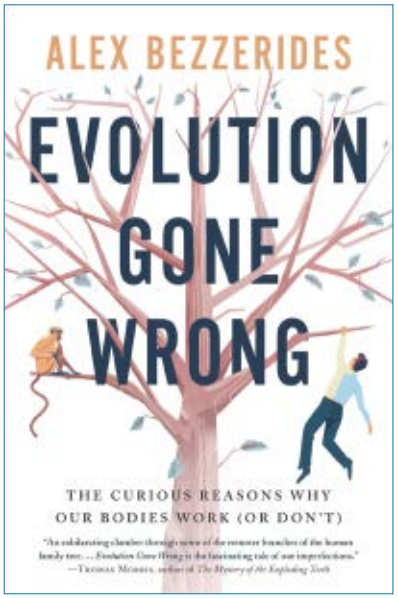
Evolution gone wrong and creation gone right

Evolution Gone Wrong: The curious reasons why our bodies work (or don't)

Alex Bezzerides

Hanover Square Press, Toronto, Ontario, 2021



Jerry Bergman

Although very readable and easy to follow, this book about claims of 'poor design' and 'useless organs' in humans has one major problem. That is the fact that most of the useless-organ claims covered have been dealt with in detail in journals and books.[1] Bezzerides holds a Ph.D. in neurobiology and behaviour, and is a professor of biology at Lewis-Clark State College in Idaho. However, as a true-believer evolutionist he sees the world, and at times distorts the world, through his 'evolution glasses'. Even when his own explanations are openly against the evidence, he tenaciously holds to them. A recurring problem is that Bezzerides seems to too-readily and uncritically accept evolutionary claims as fully valid. For example, he assumes that *Tiktaalik* is a valid evolutionary transitional form between fish and amphibians (p. 10). He totally ignores the problems with this common, but very problematic, claim.[2]

Problem teeth

At times Bezzerides even presents what he claims is an instance of poor design, then proceeds to refute his own example! The best example of this involved the analysis of results from a dental survey of his students. He found that only two students out of 70 had straight teeth with no dental problems; the rest had braces, problem wisdom teeth, and/or crooked smiles (p. xvi). He correctly concludes that these tooth problems, due to oral cavity constriction, are not poor design, but rather due to modern overly processed meals. Today's soft, cooked-food diet does not require humans to exert the necessary chewing forces that would allow their jaw muscles to develop sufficiently to make enough room in their mouth. This frequently results in crooked teeth, caused by an under-developed jaw (p. 30).

Crowded jaw

As the book is about evolution, Bezzerides then adds that evolution is partly to blame because our jaw has shrunk from our large ape jaw. The only evidence Bezzerides cites for this human jaw shrinking is his *belief* that humans evolved from an ancestor that was similar to a modern chimpanzee. Thus, he asserts, our evolutionary ancestors had a small jaw. Evolutionists do not believe that we evolved directly from a chimpanzee but that humans and chimps each evolved from some unknown common ancestor that resembled a chimp (pp. 161–162).

He correctly notes that less chewing was required as a result of the transition, from a tough-meat-and-vegetable diet that was the mainstay of our hunter-gatherer ancestors, to our modern softer-food diet. This softer diet was partly due to the invention of cooking, but especially the advent of highly processed foods (pp. 28–29). This is only a problem in modern society where the soft diet is the norm. In areas where a diet of tough meat and vegetables is still the norm, the problem of a crowded jaw occurs less often. In summary, he argues that both genetics from our ape ancestor and diet are involved. Thus, evolution and the food environment (diet) are both part of what he calls the crowded jaw problem. This assumes, as Bezzerides admits, the 'use it or lose it' theory (p. 29).

Vision problems

Another section is on cataracts and other vision problems. After noting that a meta-analysis of 60,000 Europeans determined that over half of the population studied had some visual defect, again Bezzerides claims that this vision problem was due to poor design (p. 32). This problem, he claims, was ultimately due to evolution. Specifically, he explains that the cause of the most common vision problem, myopia, is because human eyes first evolved in the ocean, where our ancestral vertebrates dwelt.

He estimates that around 375 million years ago, when our ancestors ventured onto land, their eyes, which had evolved for vision in water, had already been in that state for about

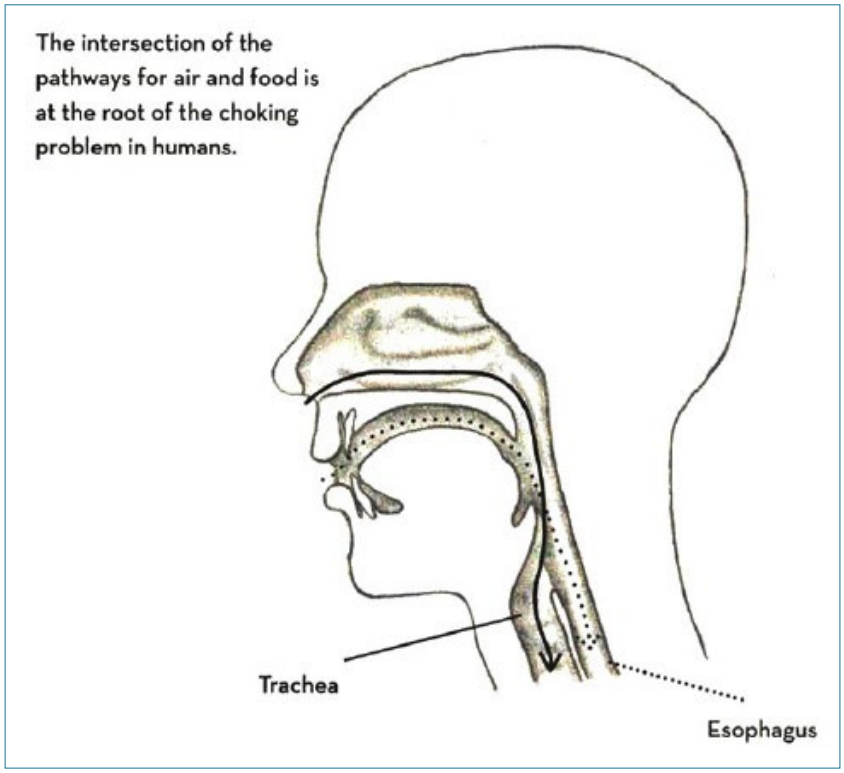


Figure 1. Illustration of the trachea–esophagus arrangement in humans from Bezzerides, p. 76. Note that Bezzerides does not include the epiglottis in his illustration which is a well-designed structure that is critical to prevent choking.

100 million years. Gradually, their vertebrate-bound eyes became air-adapted. In view of how critical vision was to survival, how these water-adapted eyes could have evolved into air-adapted ones in time for use in survival is not discussed. The eyes retained the fluids for water vision, and, as a result, never achieved the light refraction that would produce consistent image sharpness in a terrestrial environment. Because light travels slower through water than through air, and even more slowly through glass, many persons place glasses in front of their eyes to compensate for the imperfect job our corneas and lenses do in bending the light (paraphrased from pp. 40–41). This contrived explanation by Bezzerides means he avoids looking for the *real* reason for our vision problems. Discovering the real reason would allow us to better compensate for, or correct, the problem. And of course, it ignores that birds of prey, who are supposed to have had the same fish ancestors, have extremely sharp vision.

One good example of actual research into the cause of myopia (nearsightedness, when close-up objects look clear, but distant objects are blurry), found

> "… that children who spend more time outdoors are less likely to be, or to become myopic, irrespective of how much near work they do, or whether their parents are myopic. It is currently uncertain if time outdoors also blocks progression of myopia. It has been suggested that the mechanism of the protective effect of time outdoors involves light-stimulated release of dopamine from the retina, since increased dopamine release appears to inhibit increased axial elongation, which is the structural basis of myopia. This hypothesis has been supported by animal experiments which have replicated the protective effects of bright light against the development of myopia under laboratory conditions … ."[3]

In fact, Bezzerides acknowledges this research, which negates part of his evolutionary explanation (p. 65)!

When Bezzerides on occasion removes his 'evolution glasses', he displays some good insights in his writing. For example, he notes that the tear ducts that drain our eyes are smaller in women than in men. As a result, their tears are more likely to overflow down their cheeks, giving rise to the common belief that women 'tear up' more than men, and thus are more emotional (pp. 44–45).

The 'poor design' of the larynx

In the next claim, Bezzerides opines that choking on food is caused by "a universal shortcoming of human anatomy, and it seems completely backward from an evolutionary perspective" (p. 67). He concludes, "The origin of the lungs via the digestive system is at the root of the choking problem" (p. 75). Bezzerides' reasoning is based on the Darwinist belief that amphibians first evolved a breathing design which worked well for them. When they evolved into mammals (after first having become reptiles!), the amphibian design they had inherited didn't work very well. Nonetheless, mammals were stuck with it, and have supposedly been suffering ever since (pp. 77–78).

Thus, humans have inherited the problematic arrangement involving the intersection of the air (trachea) and food (esophagus) tubes, as shown in figure 1. This inherited (so-called) design 'flaw' is, Bezzerides claims, the major cause of choking. Evolutionists believe that the many changes required to evolve amphibians via reptiles into mammals did occur, yet natural selection, even faced with the selection pressure of death by choking, could not evolve the simple changes Bezzerides

argues are needed for this arrangement to be both functional and much safer for mammals.

Again, poor design is not the problem. The existing design is required for speech because the larynx must be low in the trachea. Producing speech requires the tongue, the teeth, and the entire oral cavity to be the distance above the voice box where it is found in humans. A very different design is used in other mammals, which very rarely choke on food, but also lack the ability to speak (figure 2). Thus, the design in humans allows us to speak, but presents a slightly higher risk of choking on food. As Bezzerides admits, "The low position of the non-infant human larynx does come with a benefit, and it is a pretty big benefit: it allows humans to speak" (p. 82). This is illustrated by an infant's inability to speak because their larynx is too high, which doesn't allow them to modify their oral cavity to form words (p. 84). Only when infants are between two and three years old has sufficient growth occurred, thereby causing the larynx to descend low enough for the child to use language (p. 85).

For children, choking is a special problem because their tracheal diameter is very small, like many other vessels in their body. Specifically, an infant's tracheal diameter is about the size of a green pea. This is one reason why milk and puréed foods is their main recommended diet for the first year. Another reason is that the human digestive system is not designed to digest and process even puréed fruits and vegetables until, depending on the baby's size and maturity, the baby is 4 to 6 months old.

The next greatest risk of choking is in the elderly, especially those suffering from a stroke, Parkinson's disease, or neurogenic dysphagia (i.e. difficulty in swallowing food caused by disease or impairment of the nervous system) (p. 71). Most adults, though, are at a very low risk of choking. Most commonly, choking occurs when eating too fast, trying to swallow too large a food portion, or talking and laughing while eating.

Humans swallow about 1,000 times a day, or 27 million times in an average lifespan. Consequently, life-threatening choking events are relatively rare when compared with the number of lifetime swallowing events.

The human knee

The next 'poor design' covered is the human knee, specifically the anterior cruciate ligament, which Bezzerides claims millions of individuals tear each year (p. 101). After acknowledging that this injury most commonly occurs from playing certain sports, especially football, soccer, and basketball, Bezzerides claims that the entire problem is due to our evolving from quadrupedal apes to bipedal humans. He claims that the transition occurred only 3 or 4 million years ago, which was not enough time for evolution to perfect the new knee design. Bezzerides admits that this transition lacks evidence.

For this reason, "Scientists have generated as many as 30 hypotheses that attempt to explain how and why the transition to bipedalism took place" (p. 104). Darwin devised the 'freeing of the hands' hypothesis, which argues that bipedal locomotion allowed us to use our hands to build weapons to hunt, farm, and build our homes, however crude. Soon after Darwin proposed this theory, Bezzerides notes, good arguments against it were developed. The problems with this theory have motivated many other theories to account for bipedalism; Bezzerides claims as many as 30.

One idea favoured today is the thermoregulation theory, which proposes that the main benefit of bipedalism is that humans are better able to regulate their body temperature compared to quadrupedal locomotion. Regardless of why it occurred, Bezzerides' concern is knee problems. One wonders if similar damage would occur if humans were quadrupedal. Our bipedal stance is what allows us to play many sports, such as most contact sports, but being more injury-prone is the price we pay for our bipedal design.

The fact is, the knee is the largest, most complex joint in the human body, and one of the most used (and abused) body joints. Virtually all knee problems today are due to abuse, overuse, and disease, *not* poor design. It is also, as widely acknowledged, a marvel of engineering and design. Leading design engineer Stuart Burgess has documented the irreducible complexity of the knee joint, including the four-bar hinge system.[4] He has also designed a biomimetic robotic knee joint modeled on our knee.[5,6] Furthermore, no evidence exists of knee evolution in the abundant fossil record, which should be easy to find, given that most of the knee parts are bone, which is comparatively well-preserved in the fossil record.

Back pain

A book on 'poor design' in humans would not be complete without a chapter on the claimed poor design of the human back. This book does not disappoint (p. 199). In short, evolutionists tell us that we evolved from quadrupeds and inherited a design that evolved for walking on all fours (p. 172). Bezzerides then infers that back trouble in humans is directly traceable to our primate ancestors leaving the trees for open grassland over 4 million years ago. In short, Bezzerides claims, "At the end of the day, you're a bipedal beast walking around with quadrupedal parts" (p. 199). This, he claims, explains why 61% of Americans report lower back pain, which, worldwide, is a leading cause of disability (p. 170).

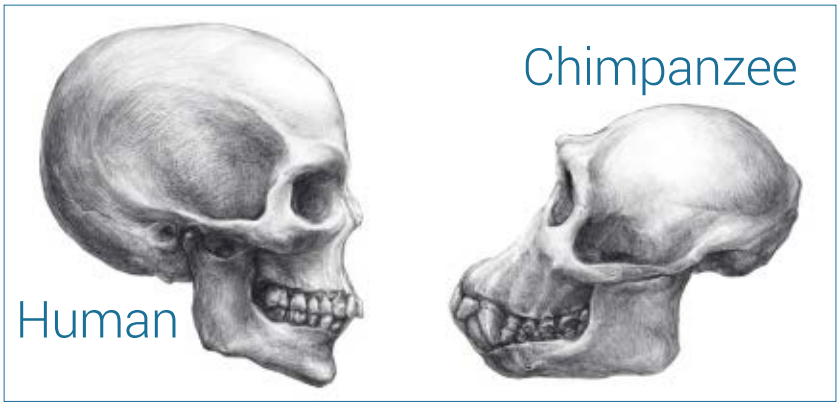


Figure 2. Facial angle contrast between humans and chimps showing that the chimp face is too long to enable them to form words, wheres the flat face of humans helps facilitate speech.

According to the evolutionary scenario, to walk on two feet, the human spine had to evolve to become very different from that of our ape cousins. The move to the forest floor supposedly caused our human ancestors' centre of gravity to shift until, after thousands of years, they could balance on two feet.

For example, the inward, or lordotic, lumbar curve must have evolved to be far enough inward so that the spine was under the head, and the centre of gravity was above the hips. The problem was, evolutionists claim, it didn't evolve quite far enough, thus we have back problems. Evidence of our evolution from quadrupedal creatures includes chimps having C-shaped spines, as do human babies. However, this design is logical, given that babies spend most of the day on their back. At around 13 months, they can stand up in their crib by holding on to the railing. Soon after, the back begins to develop the shape for human adulthood.

This chapter follows the trend of most of the rest of the book. Bezzerides gives the evolutionary explanation for back problems, then explains that it may not be the whole story. He then gives his version of the whole story. However, this accounts for most of the perceived problems, but does not provide evidence of poor design. The problem is *not* evolution resulting in poor design, but rather poor lifestyle habits. Leading expert on the human spine, Richard Porter (1935–2005), the first Sir Harry Platt professor of orthopaedic surgery at Aberdeen University,[7] explained many important good design features:

> "When you start to examine the biomechanics of the curved spine, asking why it's that shape, and what's good about it, you find that the arch of the spine has a beautiful purpose. Like the arch of a bridge, it adds strength. Because of that arch in the lumbar spine, a person with a lumbar lordosis can lift proportionally more weight than a gorilla with its kyphotic (opposite curvature) spine! So it's not surprising that treating back pain with postures and exercises that restore the lordosis works exceedingly well."[8]

Bezzerides acknowledges:

> "… that back pain occurs in epidemic proportions [in Western society] because we do not put our backs, with all their interconnected bones, muscles, ligaments, and tendons, through the same historical paces we once did. It suggests spines become misaligned and discs slip because our backs are not flexible and strong enough *owing to general inactivity* [emphasis added]" (p. 187).

Yet this alleged poor design claim is a common reason to reject the creation explanation.[9] Strong back muscles play a major role in supporting the health of the spine by maintaining the proper alignment of the spinal vertebrae. Having had back pain for years, my doctor put me on a particular exercise regimen. As a result, no more back problems.

Birth and menstruation

Most mammals do not menstruate, but reabsorb the excess blood and tissues, a process called *covert menstruation*. When the endometrium and blood are expelled, it is referred to as *overt menstruation*. Of the 5,416 species of mammals, those that undergo overt menstruation include only 181, or 5% of the total. This includes many primates, four species of bats, a rodent named the spiny mouse, and elephant shrews (pp. 211–212). The fact is that evolutionists do "not have the foggiest clue as to how or why it [menstruation] evolved. … it turns out, it is wildly complicated and still not terribly well understood" (p. 217). Nor is there any evidence of its evolution. We do know that until all of the hundreds of required parts exist, and are assembled into a functional entity, no reproduction can occur.

A good reason exists for this 'wildly complicated' system, namely that for most mammals a very short window exists during which females are fertile and it is very wasteful for the thick endometrium to be present all day, every day. The illustration Bezzerides uses to demonstrate this fact is that it is very wasteful to keep the house lights on 24/7 if visitors stop by for only a few days a month (p. 222). Moreover, "Women menstruate because their bodies have more control over their reproductive cycles than most other mammals" (p. 236).

The chapter ends with the claim that as the human brain, and thus the head, evolved and became larger, it

became more difficult to birth babies (pp. 297–301). Thus, a trade-off occurred, which resulted in one of the most commonly claimed examples of poor design, namely the problem childbirth presents for humans. Evolutionists claim that the human birth mechanism was well-designed in our evolutionary animal ancestors, but the comparatively rapid enlargement of the human brain that occurred as we evolved from ape-like ancestors created problems. They claim that the main problem is that the human birth canal diameter did not correspondingly evolve to be larger to accommodate the evolution of a larger brain.

As a result, evolutionists argue, the human head size enlarges too quickly in embryonic development, and thus is often too large to pass easily through the birth canal opening. This theory, called the *obstetrical dilemma*, is the currently dominant evolutionary thinking behind this claim.[10]

Bezzerides writes of this claim among others:

> "If we claim that organisms and their parts have been specifically designed by God, we have to account for the incompetent design of the human jaw, the narrowness of the birth canal, and our poorly designed backbone".[11]

In contrast to this common claim, evolutionary zoologist Professor Clive Bromhall writes, "it is simply not true that the [human] brain grows so fast that it 'forces' the baby to be born before it is ready", as is often claimed by evolutionists.[12] Bromhall concludes that biological research has documented that the human brain does *not* grow as fast as that of most animals. The fact is,

> "... the human body develops at an incredibly slow rate—it takes far longer [for humans] to progress from one developmental stage to the next than any other primate."[13]
>
> "The vast majority of the size difference between human brains and those of other primates results from a *far longer period of growth after the baby is born* [emphasis added]".[13]

Chimps' brains nearly double in size between birth and adulthood; in contrast, the human brain quadruples in size and does not stop growing until around age twenty.

So much for the Darwinists' claims. Actually, humans, as a whole, have *fewer* birthing problems due to the brain size and birth canal ratio issue than do many primates. The many examples include squirrel monkeys, who must actively help with their own birth.[14] Usually the claim is made that humans have more design problems that most animals. But, as Bezzerides correctly noted, some animals have birthing problems that are worse than those of humans (p. 298). And as usual with 'bad design' arguments, they ignore the biblical creation model that includes the Fall. Genesis 3:16 suggests that the obstetrical dilemma was not part of the original "very good" creation, but was the result of the Fall.

Conclusion

As a whole, this book was an excellent read. However, it assumes evolution throughout, while providing no evidence for it. One would expect that evidence for evolution would be a focus of the book, given its purported theme, noted in the title *Evolution Gone Wrong*. Instead of *Evolution Gone Wrong*, a more accurate title would be *Modern Society Gone Wrong*. Also, the author's feelings about Christianity were clear. For example, with regards to menstruation, "the Bible in the Book of Leviticus . … is chock-full of ridiculousness" (p. 217).

Aside from this problem, the book was packed full of interesting information, some of which was new to me. It is easy to see why Bezzerides was a very popular professor, which, no doubt, unfortunately allows him to influence many students to accept human evolution, given his one-sided presentation in this book.

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Fine-tuned fire

Fire-Maker: How humans were designed to harness fire and transform our planet

Michael Denton

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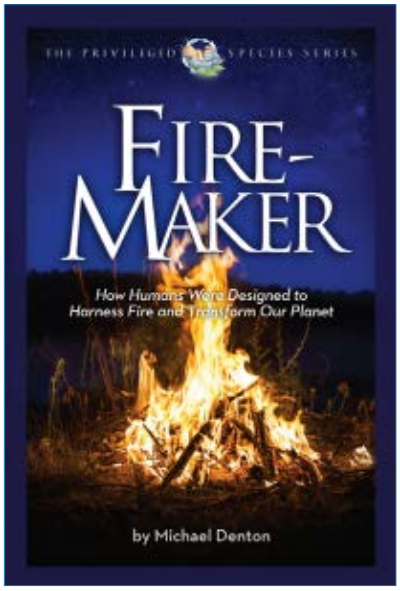
Shaun Doyle

Michael Denton is a Senior Fellow at the Discovery Institute's Center for Science and Culture. He has an M.D. from Bristol University in the UK and a Ph.D. in biochemistry from King's College in London. He has also commented extensively on the creation evolution debate, with influential books such as *Evolution: A theory in crisis*,[1] *Nature's Destiny*,[2] and *Evolution: Still a theory in crisis*.[3] These showed that there are fundamental discontinuities in biology that undermine the Darwinian expectation of a functional continuum between different creatures.

However, *Fire-Maker* has a different sort of focus. It is the first in a series of books called 'The Privileged Species Series' Denton has authored which spell out the empirical fact of *fine-tuning*—that there are many factors about our situation that have a 'Goldilocks' property—conditions that, if they were much different in any way from what they are, life like us would not be possible. Arguments of this nature concerning the constants and quantities of nature are well-known.[4] However, fine tuning goes *much* further than factors in basic physics. They also attend to all sorts of facts about the conditions within the cosmos. In circumstances that can and do obtain in the cosmos, life is impossible; it can only exist in a very specific set of circumstances. Even fewer, it turns out, enable life like us to flourish in the way we have here on Earth. It is these factors that Denton enumerates and explains in this book. In Fire-maker, he focuses on the fact that our situation is fine-tuned for making and using fire (figure 1).



Fine-tuned fire

Fire was a crucial human technological advancement. We have moved from simple metal tools to landing robots on other planets in the space of a few thousand years. And much of that advancement has happened in only the last 100 years. Denton points out that the key to all this is fire. He even cites Darwin to this effect:

> "He has discovered the art of making fire, by which hard and stringy roots can be rendered digestible, and poisonous roots or herbs innocuous. This last discovery, probably the greatest, excepting language, ever made by man, dates from before the dawn of history."[5]

Taming fire led to cooking and the invention of pottery. It also led to the discovery of charcoal, and that it can generate far greater heat than an ordinary wood fire. This allowed for the development of kilns that improved pottery technology and allowed for the birth of metallurgy. Copper and iron smelting led to all sorts of new technologies, e.g. glassmaking, alcohol, soap, and lime cement. But metallurgy is the one more than any other modern civilization would be impossible without.

Nobody can deny that human ingenuity was critical to technological advancement through the mastery of fire. However, as Denton explains, it would have also been impossible if we did not live in an environment in which we could master fire.

Denton points out that combustion is a unique chemical reaction, "providing enormous energy and heat to perform many useful tasks while at the same time being non-explosive and readily controlled" (p. 14). The low reactivity of carbon and oxygen at ambient temperatures means fire can be safely controlled and used, while also meaning carbon-based life doesn't spontaneously combust in an atmosphere of 21% oxygen. It needs the application of special catalysts (as in living systems) or heat (as in fire) to be useable for energy. It's unreactive *enough* at ambient temperatures to be safe, but still utilizable with the right sort of activation under those same conditions.

Moreover, Denton explains that charcoal reacts more vigorously with oxygen than raw wood, creating hotter temperatures needed to extract metals from their ores. But it also provides the reducing conditions needed to smelt iron. This one ingredient for two distinct tasks can be sourced merely from 'cooking' wood. As Denton points out, this is a rather "fortuitous coincidence". However, it does not end there. Charcoal being highly porous means airflow can be used to control the temperature in the kiln. As Denton says:

> "Given the range of temperatures in the cosmos and the fantastic diversity of the properties of matter, it beggars belief that the smelting temperatures of metal ores are in

reach of the temperatures that can be generated in wood or charcoal fires—a coincidence upon which the whole subsequent development of technology depended" (pp. 15–16).

A planet fine-tuned for fire

But fire itself cannot arise in ways that are useful to us in just any circumstances. As Denton explains, it requires the right sort of planet for it to work.

For instance, we need an atmosphere that can support *both* respiration and combustion. These factors are independent of each other, so an atmosphere can support respiration but not fire, and vice versa. Denton explains:

> "Because the factors which influence uptake in the lungs (including partial pressure of oxygen in the atmosphere, currently 160 mm Hg) and the factors which influence fire spread (including the percentage of oxygen, currently 21 percent, and the presence of dilutents in the atmosphere) are quite different, it is possible to engineer atmospheres capable of sustaining oxygen uptake in the lungs but not fire" (pp. 22–23).

Moreover, nitrogen has a specific heat capacity *just* high enough to make it an effective flame retardant. As Denton concludes:

> "On the one hand, the overall atmospheric pressure (currently 760 mm Hg) cannot be much increased or the work of breathing would be significantly increased, as would the risk of fire. On the other hand, it cannot be radically less or the oceans would have long ago evaporated, although recent work suggests that at times in the distant past it may have been less than half its current level" (p. 24).

Moreover, we need a rocky planet like Earth. It must have a size, mass, and gravitational field similar to Earth to sustain stable oceans and atmosphere. Gravity must be strong enough to retain gaseous nitrogen, oxygen, and carbon dioxide, but weak enough to allow for the escape of hydrogen and helium. However, this size/mass profile is also 'just right' to allow carbon-based creatures our size an upright, bipedal posture, which is of course needed to manipulate fire.

Metallurgy also requires a planet where the right elements are easily accessible and usable. Metals such as copper and iron have a high tensile strength while also being remarkably malleable and ductile at ambient temperatures on Earth. Metals soften considerably at much above ambient temperatures, and they become brittle below 0°C. Moreover, electrical conductivity of common electrical conductors like copper decreases with temperature. But it is not the conductivity profile which allows it to be made into thin wires, making ambient temperatures the best conditions in which to miniaturize motors and dynamos. Lower temperatures would mean copper would be more prone to breakage; higher temperatures make it less electrically conductive, requiring wires with a greater cross-sectional area to function, thus increasing the mass of copper needed to make motors run.

It also requires metals to be concentrated as ores in the crust for us to access. If there were less metal atoms in the Earth's crust, different properties of the mineral ores, or different viscosity properties of the crust, etc., then mineral ores might not have formed.

Fine-tuned fire fuel

However, even with the right sort of inorganic planet and the right properties of fire, fire is still not guaranteed. We need the right *fuel* as well. For that, we need wood.

But not all forms of wood are useful for technology. Twigs and grass will burn but will not produce the charcoal needed to reach temperatures at which we can smelt metals from their ores. And of course we need oxygen to make them burn. But these are not our inventions—they are both the product of *photosynthesis*. Fire is not something that we can separate from plant life—without woody plants, fire is not possible. Denton briefly mentions how the atmosphere is fit for photosynthesis, letting in the right sorts of radiation and blocking the wrong sorts.

Image: Vyacheslav Argenberg Wikimidia / CC BY 4.0

Figure 1. Conditions must be 'just right' for fire to be useful to building civilization.

But Denton concentrates most of his time on the properties of plants that make fire possible. Lignin and cellulose make the plants study and strong. For instance, lignin is sturdy and breaks down slowly, which makes soil a viable medium for plant growth. This seems to raise a chicken and egg problem: woody plants need lignin to grow well in soil, but are the only organisms that produce lignin in sufficient measure to 'feed' it to the soil.

However, Denton spends most of his time describing the transpiration system in plants. It moves water from the soil to the atmosphere much more effectively than direct evaporation from the soil. It does so by some amazing use of the physical properties of water, and pressure differentials and capillary action caused by the structure of the conduits. And of course water is a crucial component of photosynthesis. As Denton concludes:

> "Trees are only possible because of an ensemble of elements of fitness in nature—the physical factors which prevent leaves from overheating in the sun, the unique properties of the cellulose lignin composite that confer tensile strength and durability to tree trunks and promotes the formation of soil, and the unique mechanism to raise water to the top of tall trees. Trees only exist because the physical properties of water including its tensile strength and density are exactly as they are, and only because the force of surface tension generated in small, curved surfaces is as strong as it is, and only because the laws of hydraulics are precisely as they are" (p. v44).

Trees could not exist without all these uniquely fit properties. And without trees, fire would be impossible.

Fine-tuned fire-maker

But even with the fitness of our circumstances to the existence of fire, it would not be utilized if we were not fit to do so. First, we need to be terrestrial. Underwater creatures cannot master fire; their 'atmosphere' is not right for it.

But also, our bodily form makes it possible. Without our upright stance and our most impressive tool—our hands—we couldn't make and master fire.

But even with these elements in place, they would be useless for making fire if we were not the size we are. Organisms much smaller than about 1 m tall could not cut lumber needed to make charcoal or mine in solid rock. An ant-sized man could not get close enough to the flames to manipulate them without being consumed, let alone collect the lumber and mine the rocks as needed. Indeed, even ant-sized tools for ant-sized people would be useless; they don't have enough kinetic energy to work.

Organisms of our morphology much bigger than us would find it impossible, too, but for different reasons. It is an application of the *square-cube law* (figure 2), where an object's surface area increases by n^2 as its volume increases by n^3. This has a detrimental effect on muscle and bone strength as we increase the size of an animal:

> "For example, if a human were scaled up 10 times, his surface area and cross-section would be 100 (10^2) times larger—so his bones and muscles would also be 100 times stronger. However, his volume would be 1,000 (10^3) times larger—and so will his mass and weight. So his muscles and bones would be far too weak to support his weight."[6]

And since the average human thigh bone breaks under about 10 times the average human weight, the opportunities for upscaling our size are very limited. Indeed, there are grave safety risks in doing so. A small child of 20 kg can fall over with little harm, but a fully grown man may break a bone from a similar sort of fall. As the old adage goes: 'the bigger they are, the harder they fall'. When bipeds are upscaled in size to us (in the fossil record, e.g. the largest theropods), they require a very different bodyplan from us—one that is far less suited to manipulating fire than ours.

But our ability to stand up is not simply a feature of size, but also of muscle *strength*. Ants appear so much stronger than us not because their muscles are proportionately stronger. They are not.[7] Rather, it is again a function of the square-cube law. In fact, the muscles of all organisms have the same basic design. And the elements that make up muscle are tightly packed as they can conceivably be. As such, they are about as strong as they can be. This affects *all* muscle activity, from the muscles that support us standing upright, to our hand grip strength, to how well our heart pumps blood around the body.

But aside from the size and strength, we also need fast reflexes and fine motor control for our muscles. This requires a fast-functioning nervous system that is proportionate to our size. And once again, as Denton points out:

> "Consideration of the basic characteristics of nerve impulse propagation suggests that the speed of conduction in mammals is close to the maximum possible that is compatible with the electrical properties and general design of cells" (p. 60).

Not only is fire a 'Goldilocks' fit for us to make technology, but so is Goldilocks herself!

Whence the fine-tuning?

Denton in this book has only touched on a sample of the ways the cosmos is fit for life like us. Indeed, since he wrote *Fire-Maker* in 2016, he has published another four books on how many different aspects of the cosmos reveal its fine-tuned fitness for life like us.

But what can we *infer* from this fine-tuning? Denton draws a helpful distinction between the *empirical fact* of fine-tuning and design as an *explanation* of fine-tuning:

> "The unique fitness of nature for carbon-based life and intelligent beings of our biology is an empirical discovery, no matter how many cogent arguments a skeptic might introduce to counter any claim that the fitness is the result of design. Fitness is a fact … whether it is the result of design or not!" (p. 67).

But he also correctly points out:

> "Whatever the ultimate causation may eventually prove to be, as it stands, the evidence of fitness is at least *consistent* with the notion that the fine-tuning for life as it exists on Earth is the result of design" (p. 67).

And he does go further in suggesting that this fine-tuning is evidence against us being here merely as an accident of deep time and chance:

> "Although the current *Zeitgeist* would have us believe that humanity is little more than a cosmic accident, one of a million different possible outcomes that happened to arrive and survive on an unexceptional planet, the evidence examined in

this short book suggests otherwise—that whatever the causation of the fine tuning, *we are no accident of deep time and chance* [emphasis in original]" (p. 69).

Nonetheless, anyone familiar with Denton's work will know that he does *not* believe in a transcendent designer. Instead, he seems to prefer attributing the teleology of nature to "internal causal factors according to a structuralist 'laws of form' framework".[8] However, he does not press this view in this book. Rather, he focuses on the *empirical fact* of fine-tuning.

What should the biblical creationist make of this? The first thing to point out is that Denton's broad conclusion and practically all the factors he lists as fine-tuned are consistent with biblical creation. The one or two that are not are among the weakest factors he points to. Still, if such factors are required for us to be fire-makers, God plausibly parameterized the design of our environment within Creation Week to achieve similar ends. Indeed, it may be a better explanation. It fits the 'time maturation' elements into a broader parametric design schema rather than singling them out for origination by natural processes.

And there are reasons, both biblical and philosophical, to reject Denton's preferred explanation for the fine-tuning. It clearly conflicts with Scripture, and since it is God's word, it should be given epistemic priority. From the philosophical angle, however, we have no experience of the sort of 'intrinsic teleology' in nature of which Denton speaks. Rather, every instance of such extreme functional fine-tuning we have everyday experience of is produced by intelligent, personal agents. Positing a transcendent designer is much simpler, more elegant, and more intrinsically plausible than arguing for some teleological 'I don't know what' of which we have no experience. Clearly the burden of proof in on those like Denton who would seek to posit a teleological ground foundationally different from personal agency.

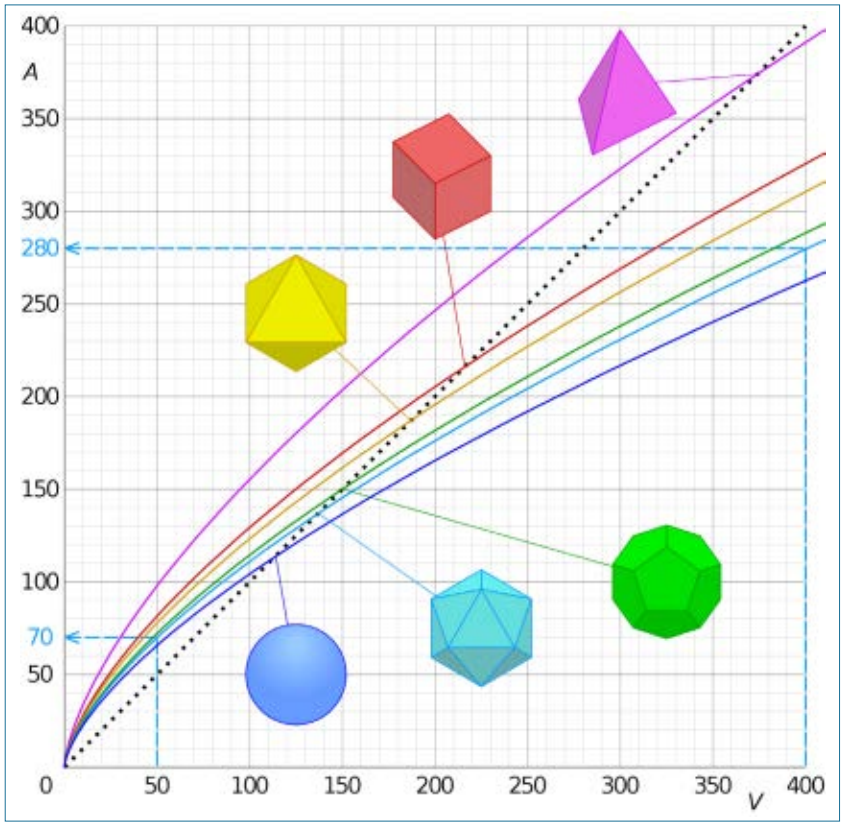


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Figure 2. Graphs of surface area *A*, against volume *V*, of all five Platonic solids and a sphere. It shows that the surface area decreases for rounder shapes (sphere being the lowest), and the surface-area-to-volume ratio decreases with increasing volume. The dashed blue lines show that when the volume of a randomly selected solid increases 8 (2^3) times, its surface area increases 4 (2^2) times. The dotted black line shows surface-area-to-volume ratio of 1.

Conclusion

Denton has done us a massive service in collating many of the empirical facts showing that nature, the earth, and humans are all together fine-tuned for making fire. There are many independent parameters that, if they were changed just a little bit in any direction, would mean we could not make fire. Nonetheless, merely noting this fine tuning cannot be an end in itself. It points beyond itself. Denton is hesitant to go where it properly points, but we do not need to be so hesitant. It is wonderfully consistent with the God of Scripture because he is the one who made nature fit for fire-makers.

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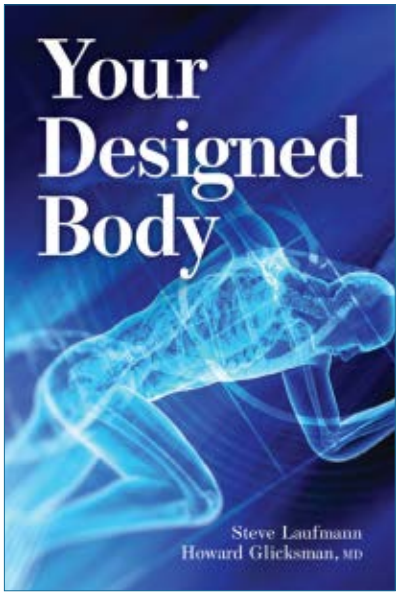
Intentional design documented

Your Designed Body

Steve Laufmann and Howard Glicksman

Discovery Institute Press, Seattle, WA, 2022



Jerry Bergman

Your Designed Body has two goals. The first half of the book is a survey of the human body's major systems that serve the specific purpose of maintaining a healthy body. This goal involves explaining human anatomy and physiology (A&P), then documenting the corresponding evidence for both design and irreducible complexity. Pages 51 to 260 are essentially an introduction to college anatomy and physiology, explained in a similar way to the coverage in high school A&P books, so that the average lay reader can follow the text. As such, it would be an excellent basic introductory A&P text for both high school and college students.

The second goal is to document that the human body is impressive evidence for intelligent design and to refute the common claims of 'poor design' and 'useless organs' that evolutionists use in an attempt to discredit teleology. The book also argues for intentional design and responds to the claim that all types of living beings are the result of random accidents (including mutations), and natural selection as evolution teaches.

The authors, Steve Laufmann, an engineer, and Howard Glickman, a medical doctor, are an ideal combination to produce an A&P book. I have never seen this combination of authors in the two dozen A&P texts I either used in teaching (or reviewed to consider using), when teaching college A&P. This engineer/medical doctor combination focuses on the body's design from an engineering-design perspective. This approach is ideal in view of the intelligent design focus of the book. Laufmann focuses on the design aspects, and Glickman, using medical examples, illustrates the physiology and what can go wrong. Both concentrated perspectives are enlightening and would significantly improve secular A&P textbooks. Most of what is being described by Laufmann and Glicksman (cognition, vision, breath, blood flow, digestion, injury repair, etc.) happens to the reader while reading and cogitating about the exquisite engineering of the human body.

Life requires designed chemical elements

For life to be alive, the chemical elements required must themselves be designed in order to function in a supportive role in life. These elements include hydrogen, carbon, nitrogen, and oxygen that collectively make up 99% of the human protoplasm mass. The other elements required for life in smaller amounts include calcium, phosphorus, sulfur, potassium, and magnesium. Last are the trace elements, comprising boron, chlorine, iron, manganese, zinc, copper, molybdenum, chromium, iodine, nickel, selenium, silicon, tin, vanadium, and over 30 others. In short, the authors show that these elements were all designed to support life.

The biological requirement for the chemical elements is also a powerful argument for design. Humans lacking necessary concentrations of molybdenum, chromium, or iodine will eventually suffer disease or death. If no molybdenum existed, presumably humans would not exist because molybdenum is an essential component of the coenzymes that are necessary for the xanthine oxidase, sulfite oxidase, and aldehyde oxidase enzymes. All these enzymes are required for human life. Molybdenum deficiency causes intellectual disability, seizures, opisthotonos (backward arching of the spine), tachycardia (irregular fast heartbeat), tachypnea (abnormally rapid breathing), headache, nausea, vomiting, lens dislocation, and coma. Before the creation of life, molybdenum needed to have been created—or another means of producing enzymes that performed the functions of xanthine oxidase, sulfite oxidase, and aldehyde oxidase was required. This sort of thing is true of the other elements necessary for life as well.

These elements are assembled to form proteins, fats, and carbohydrates which produce the cell organelles, including the nucleolus and the mitochondria. The exquisite design of a single eukaryotic cell and the molecular machines inside of it is then detailed. The cell requires certain parts to function, including the nucleus, nucleolus, mitochondria, rough endoplasmic reticulum, smooth endoplasmic reticulum, centrosomes, lysosomes, ribosomes, Golgi complex, cell membrane, nuclear envelope, and

cytoskeleton. The over 200 specialized cell types also require additional parts. For example, nerve cells require dendrites and axons, the tip of which enlarges to form the synaptic end bulb. The cell families include pluripotent stem cells, blood cells, muscle cells, fat cells, skin cells, nerve cells, and endothelial cells. Next, specific cell types including photoreceptor cells in the eye and osteocytes in bones are covered by the authors.

These cell types are grouped into tissues, including connective, epithelial, muscle, and nervous tissue. The next level includes organs, such as the kidney, and the ten organ systems including the reproductive and respiratory systems. Organs likewise require a minimum number of parts to function. For example, the human kidney requires the kidney capsule (renal capsule, once called Bowman's capsule) which consists of three connective tissue layers that cover it. Also required are the glomeruli, the renal artery, the renal cortex, the renal medulla, the renal papilla, the renal pelvis, and renal vein.

Likewise, all 78 organs in the human body contain many specialized parts. These multiple organs are grouped into ten organ systems (the skeletal, muscular, nervous, endocrine, cardiovascular, lymphatic, respiratory, digestive, urinary, and reproductive systems). Lastly, an organism is produced. A theme which seemed often implied but unstated was the irreducible complexity of the organelles, cells, tissues, organs, organ systems, and of the entire organism itself. The discussion of the organ systems documents their design, but does not directly attempt to refute their evolution. One reason is because no viable attempts, not even just-so stories, have been proposed by evolutionists to document the evolution of any human organ system (p. 400).

For many of the sections outlined above, Glicksman discusses how lacking a certain structure, or its functional equivalent, would result in disease or death. In addition, malfunctions in one system can damage other systems. For example, the main cause of kidney damage is high blood pressure. In turn, some forms of kidney problems can cause high blood pressure, damaging other organs. Excess alcohol consumption damages the pancreas. The pancreas manufactures the enzyme amylase that breaks down complex carbohydrates into glucose; it also makes trypsin and chymotrypsin to digest proteins; and lipase to break down fats. The result of pancreatic malfunction can be acute pancreatitis, which can be both very painful and life-threatening, as these digestive enzymes start to 'digest' the organ itself.

Complete androgen insensitivity syndrome

The authors also cover sexual function issues of both males and females. These discussions refute the current fad of persons born males who conclude they inhabit the wrong body and, for this reason, decide to 'transition' into a female, and vice versa. So-called transitioning is actually 'cosmetic' surgery which changes physical traits and not the DNA in the cells that determines biological sex.

However, some genetic conditions, although very rare, can cause physical sexual abnormalities.

An example is partial androgen insensitivity syndrome (AIS), in which a chromosomal male (XY) with male sex organs nonetheless has the body of a female. This is because their body does not respond fully to the male sex hormones known as *androgens* (the name means 'male-generating', and the best-known androgen is testosterone). About one in 99,000 male infants are born with this partial androgen insensitivity syndrome.

About two to five per 100,000 are born with *complete* androgen insensitivity syndrome. They are males (XY) but do not develop male external genitals because their bodies are unable to respond to male sex hormones. Such 'XY females' are the result of an abnormal X-linked gene that the mother passes to her child. The gene can't produce androgen receptors that allow the body to respond to androgens such as testosterone. The person has male sex chromosomes (one X and one Y chromosome) but a female body, including female genitals.

For the first several weeks in normal embryonic development, the embryo remains sexually undifferentiated. The gonads will become ovaries and will begin making estrogen unless testis-determining factor (TDF) is present. If TDF is present, the gonads will become testes and the body will be set down the path of becoming a male. The genetic trigger for producing testis-determining factor is on the Y chromosome. Each testis produces several other enzymes to convert cholesterol into testosterone which triggers maleness. The result is the development of the prostate gland, the penis, the testes, the scrotum, and the other male reproductive organs (p. 267).

However, for testosterone to stimulate those male characteristics, the relevant cells must have functioning receptors. Lacking androgen receptors has profound effects on numerous body organs. This small genetic defect causes the loss of certain receptors which causes numerous large body changes, and illustrates the fact that minor changes can cascade into significant design alterations. This is one of the countless examples of interwoven complexity that evolutionists struggle to explain.

This recognized genetic condition is not the cause of the concern related to the transitioning issue much talked about today. Transitioning involves a normal male or female, i.e. with no genetic abnormalities, suffering from *gender dysphoria*; a mental

condition that would seem to require a psychiatrist, not a surgeon. The transitioning issue is based on the erroneous belief that some persons are born in the wrong body.

The 'unintelligent' and 'poor design' claims

In chapter 23, the authors respond to the rash of books and articles claiming that the human body illustrates unintelligent and poor design.[1] All of the claims made in these books claiming poor design have been carefully refuted.[2] Chapter 23 focuses on the basic claims, ranging from the 'poor-design' argument to the 'no-intentional-design' claim (p. 414). One example covered in detail by Laufmann and Glicksman is the allegedly poor design claim of the human pharynx (pp. 414–422). The authors noted that many such claims are trivial, such as reading *War and Peace* and looking for less-than-perfect grammatical constructions, and missing the point and genius of the novel (p. 423).

Refuting Darwinism

The current prevailing view in science is Charles Darwin's theory that the evolution of all life occurs as a result of random changes in the genetic material (DNA) over millions of years. Some of these changes result in an organism better able to survive in the environment they live in. The result is that these organisms leave more offspring. Their offspring will eventually become more common, displacing the older design in the species. One predicted result of this process is less-than-optimal design or even poor design. As long as the organism is better able to survive and leaves more offspring than its peers, these organisms will evolve.

Laufmann and Glickman effectively challenge this Darwinian assumption alleging poor design by including the discoveries related to genetics and the finely tuned complexities of living organisms, especially in the human body. The authors argue their case both from medical insights into the workings of the human body, and from the engineering perspective that actually documents well-designed functioning systems. They stress that health and safety of humans depend on doctors knowing in detail how the body works.

Summary

Laufmann and Glickman discuss the fundamental machines that are required to produce a human body. This includes cells that are assembled into both familiar and unfamiliar structures with corresponding functions. Thirty to sixty trillion cells work together in a body that can walk, run, talk, think, and build airplanes. These organs and systems are explained by Laufmann and Glickman using examples and analogies taken from solutions to everyday problems, with a minimum of technical language. Occasional technical terms used were defined with plain English and illustrative graphics. The remainder of the book addresses the intention and purpose of the structures discussed.

The authors document that the body is not the outcome of random events, but intentionally designed. Given this, which is more likely: a blind and unintentional series of accidents, or a planned, intentional process of design and execution? Darwin first identified a mechanism for change in living organisms. He also anticipated evidence that could falsify his theory. This would include clues indicating intention, purpose, and the finely tuned properties that support life. The theological implications of *Your Designed Body* are obvious, but the identification of the designer is left open for the reader.

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Hunter's pre-Flood/Flood boundary

Max Hunter writes thought-provoking articles on his placement of the pre-Flood/Flood boundary—a boundary fraught with controversy. I welcome Hunter's latest contribution to the lower diluvial boundary somewhere in the upper mantle[1] and agree with many of his deductions.

Since most creation scientists believe that the Mesozoic and Paleozoic are Flood rocks, they conclude the lower boundary must lie either at or a little below the Cambrian/Precambrian boundary.[2-4] Dickens[5] and Dickens and Hutchison[6] place the boundary lower at the Mesoproterozoic/Neoproterozoic boundary.

I have come to a different conclusion, that most, if not all, Precambrian sedimentary and metasedimentary rocks and associated volcanic rocks are from the Flood. My reasoning is mostly based on huge Proterozoic and Archean impacts,[7,8] and that certain rather unique rocks, abundant within the Precambrian, pass upward into the Paleozoic with no break at or near the Precambrian/Cambrian boundary. So, I would agree with Hunter on including these rocks in the Flood, and that the Precambrian is not a record of Creation Week or the antediluvian period.

I also notice in his figure 7 that he has the Neogene and Paleogene deposited before the Recessive Stage of the Flood, which begins at Day 150.[9] I think this location is correct for sedimentary rocks in the high-altitude Rocky Mountain valleys and High Plains of the United States.[10,11] However, I would like to add that much of the continental shelf and slope sediments, labelled 'Neogene' and 'Paleogene' by secular scientists, would be placed *in*, and not before, the Recessive Stage. Moreover, some of the deep-sea sediments that are dated Neogene or Paleogene have ice-rafted debris. If the ice-rafted debris is interpreted correctly, icebergs can only have come from Ice Age glaciers and ice sheets, such as the Antarctic Ice Sheet. Thus, some ocean bottom Neogene and Paleogene sediments would be post-Flood.

I would also agree that the Phanerozoic starts on about Day 40. My reasoning is that it will take time to produce Precambrian features, such as rifts and basins, thick sedimentary rocks, volcanic rocks, and great deformation. It would also take time for the Great Unconformity, a vast planation surface with monadnocks, to be eroded on the top of the Precambrian rocks, even assuming very fast currents and great turbulence. Examining the Paleozoic and Mesozoic, as observed in Grand Canyon and the Grand Staircase and many other locations, reveals little deformation within the layers, implying most of the Flood catastrophism had ended before the massive deposition of Phanerozoic sediments.

I notice that Hunter still puts the peak of the Flood at Day 40, a position in disagreement with most scholars.[12] Although there are verses that make Genesis 6 and 7 seem to indicate a Flood peak at Day 40, the bulk of the evidence supports a Flood peak at about Day 150. But Day 40, I think, is significant and could divide the very catastrophic early Flood from the Great Deposition.[13] Day 40 is when the heavy, likely global, rain ended, suggesting the waning of the two biblical mechanisms of the Flood: the fountains of the great deep and the opening of the windows of heaven. This agrees with Whitcomb and Morris's deduction of a fast rise to Day 40 and then a slow, prevailing rise to Day 150[14]—i.e. a global flash flood.

Hunter writes that the Phanerozoic rocks were not deposited on continental shields. This is not correct since there are erosional remnants of Phanerozoic sedimentary rocks; for example, on the large Canadian Shield.[15] Moreover, the Vredefort impact structure is an erosional remnant from 8–11 km of erosion of the Kaapvaal Shield. The Sudbury impact structure indicates 5 km of erosion on the southern Canadian Shield.[16] This would fit with the great erosion during the Recessional Stage, revealing an exhumed erosion surface, which is likely part of the Great Unconformity.

I continue to have grave reservations about Hunter's mechanism of a decrease in gravity to allow decompression of hot, water-saturated mantle. I understand that he is attempting to account for the abundant Precambrian volcanic rocks on cratons extruded from the mantle, but what about the rest of the earth? Decompression should affect all of the earth, including the current ocean basins and the non-cratonic parts of continents. What would this combined heat and boiling water do for the Ark and its inhabitants? Although Hunter's model may be able to account for tremendous Precambrian volcanism, I question whether it is able to explain the details of the Precambrian rocks.

Hunter has previously suggested as evidence for his model the following: (1) catastrophic melting and overturn of the mantle of Mercury (he may have meant Venus), (2) impact orbits such as that of comet Shoemaker-Levy, (3) volcanic cratering and water flows on Mars, (4) the excess recession rate of the moon's orbit, (5) the possible excess precession of the perihelion of Mercury, and (6) the possible explosive origin of the asteroids.[17] I fail to see how any of these provide evidence for his model. Besides, some of the events are questionable.

The volcanism and floods on Mars are likely caused by impacts,[18] which brings up a possible explanation for the details of the Precambrian, as suggested by Oard and Froede.[19] This

possibility is that the Precambrian could be explained by impacts—an idea that still needs to be developed. We do have evidence that very large impacts occurred in the Archean and Proterozoic that would have devastated much of the earth. These impacts are best placed early in the Flood, which has profound implications for Flood models.

I would also question various correlations of Precambrian rocks and events, as I discussed in a previous forum.[20] I think this idea needs to be fleshed out in more detail rather than taking the word of Salop.[21] I still maintain my belief that Hunter's model creates more problems than it purports to solve.[22]

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» Maxwell Hunter replies:

I thank Michael Oard for his response to my Viewpoint article on the Precambrian in *Journal of Creation* **36**(3):49–59, 2022.[1] Notwithstanding our fundamentally differing perceptions regarding the means of initiation of the Flood cataclysm, and the mode of deposition of the Precambrian geologic record, Oard and I seem to be in general agreement regarding a Flood origin for the Precambrian volcanosedimentary record.

Oard claims that I place "the lower diluvial boundary somewhere in the upper mantle". To clarify, I place the pre-Flood/Flood boundary at the 660 km Discontinuity, at the base of the Transition Zone, some 250 km below the base of the Upper (Outer) Mantle.[2,3]

Oard suggests that "much of the continental shelf and slope sediments" and "some of the deep-sea sediments" labelled Neogene and Paleogene by secular workers "would be placed *in*, and not before, the Recessive Stage [emphasis in original]." Figure 7 in my article shows that is exactly where I have placed these sediments, in the Recessive Stage. Given that all these sediments were washed off the land and deposited offshore in a great jumble between Day 150 and Day 371, I cannot see how they can be 'dated' using fossils. Consequently, I don't have any confidence in 'ages' assigned these sediments by Uniformitarian workers. Any strata on the continents labelled 'Neogene' and 'Paleogene' were, I believe, deposited between Day 40 and Day 150.

"Hunter still puts the peak of the Flood at Day 40, … the bulk of the evidence supports a Flood peak at about Day 150." I note in the caption to figure 7 in my article that "Blue dotted line is water level if water extrusion from mantle not completely stopped on Day 40". I thereby allow the possibility that the water level may have risen quickly to near maximum at Day 40, and then continued to rise slowly to Day 150. I believe Day 40 is 'flagged' in the geologic record by the distinctive fossil assemblages of the 'Ediacaran Biota' and the 'Cambrian Explosion' at the top of the Precambrian and base of the Cambrian respectively. I believe these two fossil assemblages are evidence of a sudden reduction of buoyancy, due to a partial restoration of gravitational force on or about Day 40. Mantle differentiation and extrusive activity would thus have been partially shut down, causing these fossil assemblages to be dumped out

of the rising floodwaters within a few days of each other.

"Hunter writes that the Phanerozoic rocks were not deposited on continental shields." What I actually wrote was; "During the period Day 40 to Day 150, the Phanerozoic geologic record was deposited, *mostly* in the intershield areas [emphasis added]", thereby not precluding deposition of Phanerozoic strata on the shield areas.

"What would this combined heat and boiling water do for the Ark and its inhabitants?" In the caption to figure 1 of my article, I noted that the Mountains of Ararat (*Uratu*), where it is believed the Ark rested, are midway between the Central European and African Cratons. They are also remote from the nearest Precambrian shields, the Arabian–Nubian Shield of Africa and the Baltic Shield of Ukraine, where the main extrusive activity was occurring. I also wrote,

> "During extrusion of the hot Precambrian lavas, many of which were extruded subaqueously, … organisms living in intershield areas … escaped immediate destruction by the extruding hot Precambrian lavas."

As for the organisms so also for the Ark. It is, I believe, likely that the Ark and its inhabitants remained in the inter craton/shield area during the Flood, and the Ark was thus not exposed to the most intense volcanic activity with its "heat and boiling water".

"I fail to see how any of these provide evidence for his model." Oard cannot see how any of the solar system phenomena that I advocate as evidence for a historical reduction of gravitational force provide evidence for my model. Spencer (1994) proposed a creationist approach to the origin and history of the solar system which allowed for "*a major solar-system-wide catastrophe* in the history of our solar system" [emphasis added].[4] DeYoung (2000) gives us a strong hint as to what that 'major solar-system-wide catastrophe' might have been when he noted, regarding the exponent of the separation distance in the Universal Gravitational Law, "*if the exponent deviated just slightly from exactly 2, planet orbits and the entire universe would become unstable* [emphasis added]."[5]

All these phenomena are, I believe, evidence for Spencer's 'major solar-system-wide catastrophe', which I believe was due to a temporary reduction of gravitational force at some point in the history of the solar system. Does Oard believe that God created a solar system in which comets and asteroids were impacting planets and then "saw everything that He had made" and declared it to be "very good" (Gen. 1:31)? Or, can Oard find any error in the logic I used to deduce that the excess recession of the moon's orbit may be due to a temporary reduction of gravitational force?

Regarding Salop's global correlations of Precambrian strata, Oard believes "this idea needs to be fleshed out in more detail rather than taking the word of Salop." Oard seemingly implies that he can 'flesh out' a better representation of the global Precambrian geologic record than that of Salop. Soviet geologist Professor Lazarus Salop was head of the Precambrian Geology Department of the All-Union Geological Research Institute, Leningrad, USSR. Salop's work on Precambrian correlation[6] is endorsed by no lesser authority on the Precambrian than Alan M. Goodwin, of the Department of Geology, University of Toronto.[7] If Oard believes he can 'flesh out' better Precambrian correlations than those of Salop, which are so clearly evident in figure 4 of my article, then please let us see them.

Oard believes "Hunter's model creates more problems than it purports to solve." Regarding new paradigms and the creation and solution of problems, Thomas Kuhn, in his book *The Structure of Scientific Revolutions*, implied that one of the characteristics of successful new paradigms is that they create more problems than they solve. Citing the success of Plank's radiation law, and the Bohr atom model, Kuhn notes that many physicists were persuaded to adopt them even though both "*created many more problems than they solved* [emphasis added]".[8]

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Precambrian: Creation Week or Noah's Flood?

I wonder if Maxwell Hunter's research might be more relevant to Creation Week than it is to the Flood year. "Archean terrains are some of the most richly mineralized on Earth", as he writes on page 48.[1] That would fit in with Tubal-Cain who forged all kinds of tools out of bronze and iron. On p. 51, he writes that an evolutionist postulates an Archean scenario suggestive of a global flood. However, in my opinion, this would match perfectly with Days 2 and 3 of Creation Week. The continents became dry by a catastrophic act of God no earlier than Day 3.

Hunter continues on p. 51 that an evolutionist reached conclusions regarding *the earliest stages of the formation of the geologic record*. Again, I would think this typically applies to Creation Week. In my opinion it is impossible to position the earliest stages of the geologic record within the Flood year, since that would falsely imply that creation did not create any geologic record. Therefore, I believe that the Archean displacement of large masses probably is related to God's creation power. As a result, the question 'how did it happen' is not within reach of science.

On p. 55, Hunter suggested that Archean granite-greenstone is the result of a mantle plume event. Is there any experimental observation that this indeed is a possibility? Or is this just an evolutionary preliminary concept disregarding the Creator, the God for whom the globe is like clay in His Hands?

Note also that reproducing vegetation was created on Day 3. Abundant amounts of stromatolites could have started growing at an unprecedented high growth rate from then on. And since they are found in the Archean rock, it seems reasonable to consider a pre-Flood origin.

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» Maxwell Hunter replies:

Mr Heerema suggests it is impossible "to position the earliest stages of the geologic record within the Flood year. As that would falsely imply that *creation did not create any geologic record* [emphasis added]."

The 'geologic record' is comprised of rocks, and all rocks are the products of destruction. Sedimentary rocks are the end products of fragmentation, transport, deposition, and lithification, igneous rocks of melting, transport, cooling and solidification. It seems to me counterintuitive to assume that such destructive processes were occurring during a week of creation. As Oard[1] has written:

> "... why does there have to be geological activity on the earth at this time during a perfect creation? The earth was in the process of being created very good. God could have raised the dry land without erosion and sedimentation."

Further evidence of destruction in the Precambrian is the abundant fossil record of microbial organisms, including stromatolites, the result not necessarily of 'death' before the Fall, but certainly of destruction. In the Flood these organisms were destroyed; that is, rendered incapable of functioning as intended at Creation.

Archean terranes include very thick volcanic sequences including, for example, ignimbrites, the formation of which is described as "the most cataclysmic of all geological phenomena". Accretionary lapilli, the products of explosive volcanism and atmospheric ash/dust/gas (tephra) clouds also occur.[2] There is an extensive literature on diapiric uprise of mantle material, including mantle plumes.[3,4]

Probably the most compelling evidence that the Precambrian is not of Creation Week origin is the scriptural record. After the Flood, God confirmed that He had destroyed the created Earth (*éretz*) by the Flood when He told Noah (Gen. 9:11) "never again shall there be a flood to destroy the earth (*éretz*)." If the created earth was destroyed by the Flood, the Precambrian cannot be Creation Week.

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A view on our mental processes versus our physical brain

Darryl Raymond Sletten

Dr Wilder Penfield is an American-born Canadian whose research spanned the first half of the twentieth century. At the Montreal Neurological Institute, from 1934 forward, Penfield conducted research that has changed neuroscience. He used his active-brain surgical procedure to quiz epileptic patients during surgery, while applying a stimulating probe to the brain cortex. Penfield's research has changed neuroscience in profound ways. He developed a better understanding of brain function and established a hypothesis on how the immaterial mind and organic brain interact. Penfield opened the Montreal Neurological Institute and Hospital through funding from David Rockefeller.

This article consists of more discoveries into mind/brain mental processes. It also discusses whether there is a connection between the mind and the soul, plus our spirit, with respect to a physical brain interaction. Dualism and materialism are discussed throughout this article. Dualism encompasses both non-material mind and material brain action, whereas materialism only involves material brain action!

The question of brain and mind

Does the physical brain account for the human mind? The answer to that question has huge implications. Atheistic evolutionists must believe that it does—that there is nothing spiritual about our thought processes. But if the physical brain cannot account for the mind—the thinking and creative part of our being—then it gives credence to the idea that we are created in the image of God, separate from the animals. So, everything hinges on this vital question!

There is no specific Bible verse that explains our mental abilities in much depth. Portions of two verses in Daniel 2:28–29 state, "Your dream, and the visions of your head as you lay in bed are these: To you, O king, as you lay in bed came thoughts … ." And in Romans 12:2, "Do not be conformed to this world, but be transformed by the renewal of your mind." According to Matthew 22:37: "You shall love the Lord your God with all your heart and with all your soul and with all your mind."

In *The Bible Knowledge Commentary* we read, "The key to this change is the mind, the control center of our attitudes, thoughts, feelings, and actions. As one's mind keeps on being made new by spiritual input, his lifestyle keeps on being renewed."[1]

Introducing Dr Wilder Penfield

Dr Wilder Penfield (figure 1), was made a Companion of the Order of Canada and was inducted into the Canadian Medical Hall of Fame in 1994. In his book *The Mystery of the Mind*, Penfield developed a hypothesis about how the mind and organic brain may work in collusion with each other. He saw the mind/brain interaction system as having three separate functions. There is a mind itself, then the highest brain mechanism, and, lastly, the automaton (the autonomic nervous system, which follows a predetermined sequence of operations or responds to predetermined instructions). The mind can give direction only through the mind's brain mechanism. Purpose comes to it from outside its own mechanism.[2] The author says:

> "This suggests the mind must have a supply of energy available to it for independent action. We may assume then, that if a mind can give directions minutes in advance, it must also give directions split seconds in advance. I assume that the mind directs, and the mind-mechanism executes. It carries a message. As Hippocrates expressed it so long ago, 'the brain is messenger' to consciousness. Or, as one might express it now, the brain's highest mechanism is *messenger* between mind and the other mechanisms of the brain [emphasis in original]."[3]

Penfield wrote:

> "It is the mind (not the brain) that watches and at the same time directs. Has the mind, then, a memory of its own? No. There is no evidence to suggest it. If it has, there exists a memory mechanism of an entirely different and unsuspected order. The mind has no practical need for other memory sense, to the highest brain-mechanism. It can open the files of remembrance in a flash."[4]

Penfield states:

> "… one can understand the complexity and efficiency of the reflex coordinating an integrative action of the brain. In it, the automatic computer and the highest brain mechanism play interactive roles, selectively inhibitory and purposeful.[5]

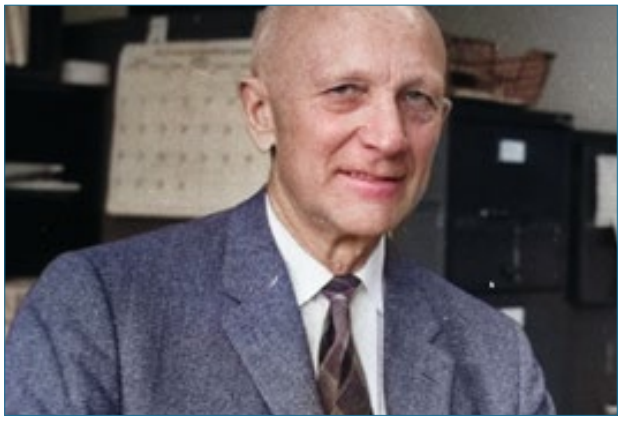

Image: United States National Library of Medicine, Wikimedia / Public Domain (colourized)

Figure 1. Dr Wilder Graves Penfield OM CC CMG FRS (1891–1976) was an American-Canadian neurosurgeon.

"Does this explain the action of the mind? Can reflex action in the end, account for it? After years of studying emerging mechanisms within the human brain, my own answer is *No!* [emphasis in original]."[5]

Penfield's first experiment

Brain surgical procedures were used by Penfield in his study of the brain. His writings are the result of actual experiences, not purely philosophical exercises. Below are the details of a brain operation he performed on an epileptic patient:

"We have found that a gentle electrical current interferes with the function of the speech mechanism. One touches the cortex with a stimulating electrode and, since the brain is not sensitive, the patient does not realize that this has made him aphasic until he tries to speak, or to understand speech, and is unable to do so."[6]

"One of my associates began to show the patient a series of pictures on the other side of a sterile screen. C.H. named each picture accurately at first. Then, before the picture of a butterfly was shown to him, I applied the electrode where I supposed the speech cortex to be. He remained silent for a time. Then he snapped his finger as though in exasperation. I withdrew the electrode and he spoke at once: 'Now I can talk', he said. 'Butterfly', 'I could not get that word butterfly, so I tried to get the word moth.' It is clear that while the speech mechanism was temporarily blocked, the patient could perceive the meaning of the picture of the butterfly. He made a conscious effort to get the corresponding word. Then, not understanding why he could not do so, he tuned back for a second time to the interpretive mechanism, which was well away from the interfering of the electric current, and found a second concept that he considered the closest thing to a butterfly. He must have presented that to the speech mechanism, only to draw another blank."[6]

"The patient's simple statement startled me. He was calling on two brain-mechanisms alternately and at will. He had focused his attention on the cards and set himself the purpose of recognizing and naming each picture as it came along. At first each picture was inspected in the stream of consciousness. It was identified, named, and recorded. He was using areas of cerebral cortex that, at birth, had been uncommitted as to function. Evidently, the highest brain-mechanism, impelled by mind-decision, can carry out these transactions, calling upon previously established, conditioned reflexes one by one. When I paralyzed his speech mechanisms he was puzzled. Then he decided what to do. He reconsidered the concept 'butterfly' and summoned the nearest thing to butterfly, that was stored away in his concept mechanism. When the concept 'moth' was selected and presented in the stream of consciousness, the mind approved and the highest mechanism flashed this non-verbal concept of moth to the speech mechanism. But the word for 'moth' did not present itself in the stream of consciousness as he expected. He remained silent, then expressed his exasperation by snapping the fingers and thumb of his right hand. That he could do without making use of the special speech mechanism. Finally, when I removed my interfering electrode from the cortex, he explained the whole experience with a feeling of relief, using words that were appropriate to his thought. *He* got the words from the speech mechanism when *he* presented concepts to it. For the word 'he' in this introspection, one may substitute the word *mind*. Its action is not automatic."[7]

"As I visualize it, a reasonable, explanatory hypothesis can be constructed as follows: because I had asked the patient to do so, he turned his attention to the naming of cards [pictures], programming the brain to that end through the highest brain mechanism. I can say only that the decision came from his mind. Neuronal action began in the highest brain-mechanism. Here is the meeting of the mind and the brain. The psychophysical frontier is here. The frontier is being crossed from mind to brain. The frontier is also being crossed from brain to mind since the mind is conscious of the meaning of the neuronal succession that determines the content of the stream of consciousness. The neuronal action is automatic as it is in any computer."[8]

"In conformity with the mind's decision, the highest mechanism sends neuronal messages to the other mechanisms in the brain. The messages go, I suppose, in the form of neuronal potentials arranged in a meaningful pattern and they are sent, in each case, to the appropriate target gray matter. They cause the individual to turn his gaze and focus his eyes on the matter in question. They cause him to interpret what he sees, to select words that will express a meaning."[8]

"This is hypothetical thinking, of course. It is clear

that much is accomplished by automatic and reflex mechanisms. But what the mind does is different. It is not to be accounted for by any neuronal mechanism that I can discover."[8]

Additional experiments

From another surgical experience, Penfield says:

"The patient's mind, which is considering the situation in such an aloof and critical manner, can only be something quite apart from neuronal reflex action. … The fact that there should be no confusion in the conscious state suggests that, although the content of consciousness depends in large measure on neuronal activity, awareness itself does not."[9]

The information following simplifies this neurosurgeon's intricate, detailed report on his brain surgical procedure.

First, even the memory of a physical event must result from it being observed by a non-physical intelligence or there would be no memory imprinted upon the physical brain. Memory involves thoughts, and thoughts are clearly not physical because they include non-physical ideas, such as truth, justice, perfection, etc. Amazingly, because of the mysterious connection of the mind to the brain, what the mind thinks is recorded within the brain.[10]

Obviously, no event of itself creates memories. Nor is the mechanism (whatever it may be, such as a video camera) by which a memory is recorded the *source* of either the event or a memory thereof. The brain is no more the *source* of the memories physically stored on it than a video or DVD or audiocassette or computer is the *source* of sights and sounds physically stored on it.[10]

Again, Penfield described the brain as a computer programmed by something independent of itself, the mind. The brain can have memories of ideas or events implanted upon its physical structure, but this does not mean the computer (or brain) *originated* such ideas or events. Just as an intelligence that exists outside, and is independent of, the computer must put into it whatever memory it has. So, it is the mind (the independent intelligence) that imprints memories on the brain.[10]

Lines of reasoning

Dr Wilder Penfield performed hundreds of stimulations of the brain surface. He had three lines of reasoning as evidence for dualism: his inability to stimulate intellectual thought, the inability of seizures to cause intellectual thought, and his inability to stimulate the will: so he concluded that the intellect and the will are not from the brain, which is precisely what Aristotle said.[11]

An interesting podcast note reads as follows:

"Dr Egnor goes on to explain that the brain does not experience pain so a neurosurgery patient can comfortably remain conscious with only local anesthetic.

Image: Wellcome Images, Wikimedia / CC-BY-4.0 (colourized)

Figure 2. Sir John Carew Eccles AC FRS FRACP FRSNZ FAA (1903–1997) was an Australian neurophysiologist and philosopher who won the 1963 Nobel Prize in Physiology or Medicine for his work on the synapse.

The surgeon can then communicate with the patient to be sure that the treatment is not damaging speech or movement."[11]

Additional Investigations

Sir John Eccles (fig. 2), Ph.D., neurophysiology and Nobel Prize winner, and a Dr Robinson, Ph.D., psychology, discussed the research of three groups of scientists: Robert Porter and Cobie Brinkman, Nils Lassen and Per Roland, plus Hans Kornhuber and Luder Deeke—all of whom produced startling and undeniable evidence that a mental intention preceded an actual neuronal firing (in the brain)—thereby establishing that the mind is not the same thing as the brain, but a separate entity altogether.[12]

The experiments of Benjamin Libet (figure 3), a mid-to-late 20th-century neuroscientist, studied the precise timing of electrical activity in the brain and conscious decisions to do simple tasks such as pushing a button. He found that we have preconscious impulses, characterized by spikes in brain waves that precede conscious decisions by about a half second. The results seem to indicate that what may seem to be a freely made decision is actually a decision that is made unconsciously, *before* one is consciously aware of having made it. If this is correct, then there seems to be no room to say that we are consciously in *control* of our decisions.[13]

"But Libet was an excellent scientist so he tested the hypothesis that free will wasn't real by asking the volunteers to occasionally veto their decision after making it—to decide to push the button but to then immediately decide not to. He found that there was no brain wave associated with the veto—i.e. *the veto was not from the brain*. Thus, the veto was immaterial and independent of brain processes, and it corresponded to free will. Libet concluded that our decisions consisted of two parts: a preconscious 'temptation' and a conscious acceptance or veto. The temptation was associated with brain activity

> and might in that sense be considered involuntary (even that is problematic). But the acceptance or veto of the temptation was *not* determined by brain activity and appeared to be immaterial (i.e. spiritual) in origin. Libet quipped that he 'hadn't proven free will, per se, but he had proved "free won't"' [emphasis in original]."[13]

Michael Egnor (figure 4), a neurosurgeon, writes that "Materialists sometimes misrepresent the evidence for free will, especially concerning Benjamin Libet's work!",[14] and "we most certainly have free will. We can see this from three perspectives: scientific, philosophical and logical."[14] Note that Libet later did believe in free will; it was the popular science media that didn't believe.[14]

The four neuroscience expressions used by Benjamin Libet are: 'readiness potential', 'free won't', 'contra-casual free will', and 'both wrist flexing and flicking'. Readiness potential (RP) is the state prior to the conscious decision to move one's hand in an apparent act of free will, and is unconscious brain activity detectable by EEG recording.[14]

Alfred Mele, in his book *Effective Intentions: The power of conscious will*, criticized the interpretation of the Libet results on two grounds. First, the mere appearance of RP a half second or more before the action in no way makes RP the cause of the action. It may simply mark the beginning of forming an intention to act! [15] (Note: Other neuroscience expressions will not be covered due to content restraint, but are also critiqued by Mele. Interestingly, Libet has come around to Mele's way of thinking and now believes that his experiments leave some room for free will, or at least free 'won't'.)

Concerning additional thoughts about free will, Keaton Halley responded involving experiments about physical processes involving free will:

> "I will argue that there is no reason to challenge the research *per se*, only the interpretations placed on it. … Here are seven reasons why these experimental results do not undermine human freedom:
>
> 1. It is possible that there is a lag time between making a decision and becoming aware of it. …
> 2. Making a decision may not take place in an instant, but involve a process. …
> 3. Brain activity is not the same as brain causation. …
> 4. The predictive success based on brain scans was not 100%. …
> 5. In a 2007 study by Brass and Haggard, it was found that even after a self-reported decision people still had the power to change their minds before they performed the act. …
> 6. Lack of freedom in one area wouldn't prove a total lack of freedom. …
> 7. The argument against free will is self-refuting. …"[16]

Egnor notes that "'the brain can be cut in half, but the intellect and the will cannot.' That in itself implies that mind and brain are not the same thing."[17]

Egnor argues that the emergence of the mind from the brain is not possible because

> "… no properties of the mind have any overlap with the properties of the brain. Thought and matter are not similar in any way. Matter has extension in space and mass."[18]
>
> "I think the best explanation of the relationship of the mind to the brain is Aristotelian hylo-morphism which is the viewpoint that the soul is the form of the body and that certain powers of the soul, particularly the intellect and will, are not generated by matter but are immaterial things—what Thomas Aquinas would call the 'spirit'. But other properties of the mind, like perception and memory and imagination are physical. They are directly related to brain matter and they are generated by brain matter. I think that is the best explanation philosophically for what we find in neuroscience."[19]
>
> In a discussion with Bruce Gordon, Egnor states:
>
> "'You also never have morality seizures. You never have seizures where you compulsively recite the 10 commandments,' and Dr Penfield says, 'Why not? Why aren't there intellectual seizures, if the brain is a source of the intellect?' Of course, Aristotle and St. Thomas, thousands of years ago said the intellect is not material. It doesn't come from the body."[20]

Commenting on physicist Sabine Hossenfelder and biologist Jerry Coyne, both of whom deny free will, Egnor asserts:

> "*Rational* appetite is inclination to act based on reason, not on perceptions or imagination. … My decision about whether to eat a piece of cake because of its appearance and how I imagine it will taste is fundamentally different from my decision about whether I will break my diet in order to do so. One inclination—my sensitive appetite—is based on concrete perception. The other inclination—to follow my diet—is based on abstract reason [emphasis in original]."[21]
>
> "Only abstract reason / rational appetite is the *will* part of free will. Sensitive appetite is not part of the will—it is a passion based wholly on material factors—my brain chemistry, etc. Sensitive appetite is not free—this kind of appetite is indeed dictated by my molecules and neurotransmitters. I can condition and override it but in itself, it is wholly material and subject to the laws of nature [emphases in original]."[21]
>
> Michael Egnor also states:
>
> "Researchers either assume or find it easy to conclude that spiritual experience is *caused* by brain states. This is, of course, not true: spiritual experience is abstract and mediated by the immaterial intellect and will [emphasis in original]."[22]
>
> The Discovery Institute's David Kitzhoffer writes:
>
> "There is an immaterial aspecta spiritual aspect to the human soul that can be demonstrated by science, and it leaves its signature, sadly, in this peculiar aspect

of epilepsy. [Egnor said that] 'patients (epileptic) never think abstractly as a part of the seizure. There has never been a report in the medical literature of an intellectual seizure'… . Penfield concluded, quite reasonably, that this was because intellectual thought didn't come from the brain. Intellectual thought (Penfield called it the 'Mind') is an immaterial human power. Dr. Penfield began his career as a 'Materialist'. He ended it as a convinced 'Dualist.'"[23]

Spiritual connections

The Bible Dictionary explains 'mind', in the Old Testament, as the intellect with all its capacities. 'Soul' is referred to as psyche. Mind and psyche are used interchangeably. (The individual self, or each person *is* unique.)

The Berean Call Staff wrote:

"Hebrews 4:12 tells us that the Word of God is living and active and sharper than any two-edged sword, piercing even to the 'dividing asunder of soul and spirit'. There is a distinction between the soul and spirit and it takes an extremely sharp (i.e. supernatural) instrument to discern it. Consequently, any attempt at human definition must fall short. The soul is said to include the mind, the will, and the emotions. Jesus, in His humanity, said that His soul was 'exceedingly sorrowful, even unto death …' (Matthew 26:38)."[24]

Other important thoughts

Egnor states:

"'I believe 'consciousness' is the same kind of empty narrative gloss applied to the mind. Man has a soul, and the mind is several powers of the soul—sensation, perception, sensus communis, imagination, memory, rational appetite, reason and will. [Note: Again, some of the above properties are generated by brain matter, as previously mentioned.] By 'consciousness' we just mean the exercise of those powers. … Mechanical philosophy is the assertion that nature and man are *machines* of a sort. … . It is an egregious philosophical and scientific mistake but that is beyond our scope here [emphasis added]."[25]

Egnor also says:

"I believe that 'consciousness' became a concept in the early modern era because of this machine analogy. Machines, after all, can be *turned on and off*. If the body is a machine, life is the *on* position of the switch, and death is the *off* position. … There are strong scientific reasons to reject this notion that the soul, including the powers of the mind, can be extinguished in the sense of being 'switched off' [emphases in original]."[25]

Egnor goes on to list a number of reasons to dispute the mechanical philosophy:

Image: Author unknown / Wikimedia (colourized)

Figure 3. Dr Benjamin Libet (1916–2007) was an American neuroscientist who was a pioneer in the field of human consciousness, and in 2003, the first recipient of the Virtual Nobel Prize in Psychology from the University of Klagenfurt.

"When we sleep, although we would commonly be called 'unconscious', we remain aware to a significant extent of our surroundings. We wake up to noise or pain or cold. … During sleep, we are aware of dreams. … Our minds [a part of our soul] are never off; we just have states in which one or more powers of the mind—sensation or perception or memory, etc.—are temporarily inactive. … We are never switched off—we are never unconscious—not in sleep, not under anesthesia, not in a coma and not even after death."[25]

Is consciousness in the cerebral cortex or elsewhere in the brain? Neuroscientist Mark Solms and neurosurgeon Michael Egnor had a debate/discussion on this subject. Mark Solms explains that "the source of consciousness in the brain is in fact in the brain stem" not the cerebral cortex, as is almost universally assumed. He explains his reasoning with evidence.[26] Egnor responds that his own clinical experience supports that view, and the view that the mind is not simply 'what the brain does', as some popular neuroscientists claim.[26]

According to philosophy of mind researcher Dr Gualtiero Piccinni:

"Contrary to what many doctors apparently assume, there is overwhelming evidence that hydranencephalic children, who lack a cerebral cortex, are creature conscious in a robust sense. That is, they have a sleep-wake cycle, they respond appropriately to some features of stimuli, and they express emotions and preferences. But are they phenomenally conscious? Since they can't give linguistic reports, it's hard to tell."[27]

Michael Egnor notes:

"So, the mind cannot arise wholly from matter because intentionality is not a property of matter. The existence of the mind refutes materialism because the mind is characterized by a power that matter does not have. Intentionality, like design, is a shoal on which materialism wrecks."[28]

Egnor also cites Oxford philosopher Ferdinand Schiller, who in 1891 proposed:

> "'… matter is not what produces consciousness but what limited and confines its intensity within certain limits. ... This explanation admits the connection of matter and consciousness, but contends that the course of interpretation must proceed in the contrary direction. … It is an explanation the possibility of which no evidence in favor materialism can possibly affect.'"[29]

Egnor goes on to say:

> "Schiller argued that brain injuries are better understood as preventing the manifestation of consciousness than as extinguishing it. He suggested that, with regard to memory, it is *forgetfulness* and not memory that needs to be explained by neuroscience. For example, he noted the remarkable clarity of total recall that many people have under hypnosis … . The recent research at Cornell supports that perspective. It is evidence for a dualist and even an idealist view of the mind and brain."[29]

An article entitled "The Mind vs Brain Debate (What is Consciousness?)", by Christina Sarich, poses some interesting questions and answers concerning consciousness and the mind. Now concerning phantom limb pain, "is it the mind feeling the limb [pain] or the erroneous assumption of the brain? Why would the brain feel something that wasn't there? Is this true consciousness?"[30]

Further in the article it is stated that:

> "… the wave/particle theory [by physicists] also describes the presence of greater intelligence at least insofar as understanding the power of the mind. Not only is intelligence not relegated to the workings of the brain, but it is also not even relegated to the atoms and quarks we observe. When looking at waves and particles and their behavior physicists find that they act differently once observed. Consciousness, in fact, may create them. … Consciousness or mind is not matter. But even quantum mechanics is having a hard time describing consciousness."[30]

Now concerning awareness,

> "Although it is theorized that memories in the brain are just stored chemical structures such as in a neural network, some doctors are pointing to evidence of awareness once the physical structure of the brain is considered dead. … Perhaps we will yoke our mind with the body (or brain) by the contemplation of consciousness itself."[30] (A question arises: what is the exact connection between the mind and consciousness or even awareness?)

Kelsey Ichikawa—a recent Harvard neuroscientist graduate who discussed the snares into which misinterpretation can lead us—has recently published a brilliant piece on the pitfalls of functional magnetic resonance imaging (fMRI) of the brain.[31] Egnor states:

> "A major thrust of neuroscience research in the last couple of decades has been the use of fMRI to correlate brain activity with thinking and to draw conclusions about the physical basis of the mind. A few points about fMRI imaging are important to note:
>
> 1. fMRI imaging doesn't see brain activity directly. fMRI imaging detects changes in regional blood flow in the brain, and we know from research over a century ago that activity in a part of the brain correlates more or less with changes in blood flow to that part of the brain. When neurons in a region of the brain become active, blood flow in that region increases.
> 2. The changes in blood flow do not occur simultaneously with the brain activity. There is a lag of anywhere from a few seconds to upwards of a minute from the neuronal activity to the uptick in blood flow. *The time resolution of fMRI imaging for brain activity is not particularly good* [emphasis added].
> 3. MRI imaging produces rather fuzzy pictures of the brain. …
>
> Ichikawa gives an example of the imprecision and potential for bias in fMRI imaging."[31]

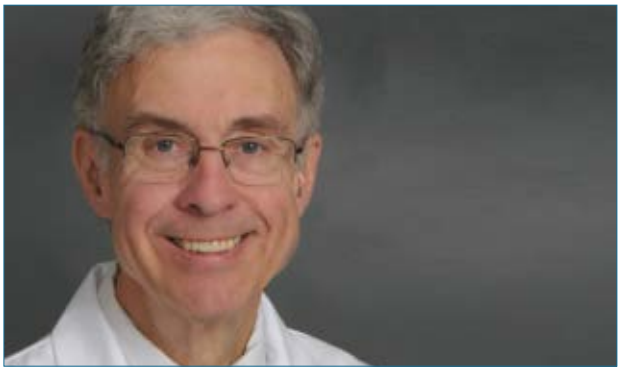

Image: Biography photo at Discovery Institute

Figure 4. Dr Michael Egnor is Professor of Neurosurgery and Pediatrics at State University of New York, Stony Brook.

(Space constraints preclude discussion of many additional examples.)

As discussed by Egnor, Ishikawa also refers to a famous fMRI study in which a researcher discovered brain activity in a dead salmon using standard statistical methods:

> "Craig Bennett, a postdoctoral researcher at the Univ. of California, Santa Barbara did the MRI scanning of the dead salmon. To his surprise, 'the dead fish's brain exhibited increased activity for emotional images—implying a sensitive, if not alive, salmon.' Even in a dead salmon's brain, the MRI scanner detected enough noise that some voxels exhibited statistically significant correlations. By failing to correct for multiple comparisons, Bennett and his colleagues 'discovered' illusory brain activity. Ichikawa does a great job of pointing out the myriad pitfalls of fMRI research, which is a very active line of neuroscience research in the 21st century."[31]

The Mind and the Brain: Neuroplasticity and the power of mental force, by Dr Jeffrey M. Schwartz and

Sharon Begley, contains interesting mind/brain information. These two authors demonstrated that the human mind is an independent entity that can shape and control the functioning of the physical brain.[32]

Conclusion and personal reflections

Experimental evidence from Dr Penfield plus the credible information from others included in this article lead me to conclude that our minds, our inner being, cannot be accounted for by our physical brain. Some further thoughts to ponder that involve our spirit, soul, and body are: it appears that man's spirit itself communicates with God. I suggest that man's soul (mind) communicates with the spiritual realm through the spirit of man. Also, the soul communicates with the physical realm through the body. 'Soul', which is *psyche* in Greek, is the part of mankind that lives on after death. Luke 1:46–47 states, "My soul magnifies the Lord, and my spirit has exalted in God my Savior."

Concerning when and where believers go after death, when Jesus hung on the Cross where He was executed, there were two criminals along with Jesus. One criminal said, "'Jesus, remember me when you come into your kingdom.' And Jesus replied, 'Truly, I say to you, today you will be with me in paradise'" (Luke 23:42–43).

I believe there is a mind or soul connection, plus our spirit, with respect to a physical brain interaction system. This shows a distinction between the physical brain and a non-physical mind or soul. Our mental faculties and our physical brain are a vital part of the creation of mankind. Where would we be without our mental abilities, especially concerning our salvation in Jesus Christ? This truly is a non-physical mental process. This conscious decision is the most important mental one we can ever make. It will both divinely transform our here-and-now and determine our eternal destiny.

> "Do not be conformed to this world, but be transformed by the renewal of your mind, that by testing you may discern what is the will of God, what is good and acceptable and perfect" (Romans 12:2).
>
> "… because, if you confess with your mouth that Jesus is Lord and believe in your heart that God raised him from the dead, you will be saved. For with the heart one believes and is justified, and with the mouth one confesses and is saved" (Romans 10:9–10).

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Is our universe inside a black hole?

Alex Williams

Physicists have postulated that according to General Relativity Theory our universe might exist inside a black hole. However, they have no clear observational or experimental technique to determine if this is true or not. One reason is that black holes themselves are such mysterious objects. In this article I explore what we know about black holes and compare it with similar things that we know about the universe. While the question appears to remain open, I favour a negative answer to the title question. This paradox may be just one more of the multitude of mysteries that pervade the universe and our place within it.

Our universe is curiously enigmatic in a multitude of ways.[1,2] One example is that the leading contemporary theory for its origin, the inflationary Lambda Cold Dark Matter (big bang) Model, is built on (among other things) three main components—inflation, dark matter, and dark energy—of which we have "no direct evidence or fundamental understanding".[3] A bizarre alternative theory that has emerged out of this intellectual wilderness is that we might be living inside a black hole. Experts promoting this idea include award-winning physicist and TV science guru Professor Brian Cox, together with CERN colleague Dr James Beacham,[4] Spanish cosmologist Professor Enrique Gaztanaga, who published his Black Hole Universe (BHU) Theory in an article entitled "How the Big Bang ends up inside a Black Hole,"[3] and the Perimeter Institute for Theoretical Physics in their 2015 cover story in *Scientific American*, "The Black Hole at the Birth of the Universe".[5]

Cox and Beacham based their arguments upon (i) thermodynamics and probability, which create a paradox in big bang theory, and (ii) the Schwarzschild radius of the observable universe approximately coincides with its Hubble radius, and this might resolve the paradox by placing us inside a black hole. Gaztanaga's theory posits the origin of our universe in the dissolution of a prior universe that existed inside its own gravitational radius (i.e. already inside a black hole) which collapsed down to a matter density equivalent to that of atomic nuclei, and then 'bounced' back into an expanding phase, which we now see happening around us today. The Perimeter Institute argument is based on the holographic principle and argues that a single black hole creation event in a four-dimensional universe could have given birth to our three-dimensional universe.

What are we to make of all this? I explore the idea in this article, but without expecting to offer much that is new. In 1980 Nobel Prize winning American cosmologist Joseph Peebles wrote a textbook entitled *The Large-Scale Structure of the Universe*, which was reprinted in 2020 on the grounds that it was still the "essential introduction to this vital area of research." However, in the [original] preface Peebles had said:

> "… the links between theory and observation … [which] is the main point of the subject … is not treated at length because I think there are too many options, all apparently viable but none particularly compelling. It seems likely that the game of inventing scenarios will go through several more iterations before a secure picture emerges."[6]

Clearly, this 'game of inventing scenarios' to explain the universe is still going strong more than four decades later, and a 'secure picture' is still very far from 'emerging' any time soon!

What do we know about black holes?

In 1915, in the trenches on the Russian Front during World War I, German physicist Karl Schwarzschild read Einstein's newly published General Relativity Theory (GRT). He soon discovered an exact solution (which Einstein had failed to do) that predicted the potential existence of black holes in any non-rotating point or spherical mass.[7] No-one knew about black holes at the time, so this prediction remained hidden within the mathematics. Schwarzschild's equation contained two points where the result became 'singular' (went to infinity); one was at zero radius (i.e. where all the matter is squashed up into zero volume of 4-dimensional spacetime),[8] and the other was at a radius that he called the 'characteristic gravitational radius' for that mass, and this is now called the *Schwarzschild radius*.[7]

In 1939, Robert Oppenheimer and Hartland Snyder calculated that when a large star has used up all its thermonuclear fuel it could collapse indefinitely inside this 'gravitational radius',[9] but such a collapsed object had not yet been identified with any known astronomical entity. In 1956 Wolfgang Rindler introduced the term 'event horizon' to describe the perimeter marked out by the gravitational radius,[10] and during the 1960s the collapsed object became known as a 'black hole.'[11]

In 1965 Roger Penrose took Schwarzschild's solution together with Oppenheimer and Snyder's 'collapsed star' theory and generalized them to non-spherical initial mass

conditions.[12] For this work he was awarded a half-share in the 2020 Nobel Prize in physics "for the discovery that black hole formation is a robust prediction of the general theory of relativity".[13] In 1972 the first black hole Cygnus X-1 was identified from its X-ray emissions and its gravitational effects on a companion star.[14]

Schwarzschild's equation applies only to a stationary object, but it is expected that most real black holes will have angular momentum (spin), and in 1963 Roy Kerr found an exact solution that applies to a spinning mass.[15] A spinning black hole has a more complex boundary than a stationary one because it drags the surrounding spacetime with it,[16] but all of this happens inside the Schwarzschild radius. It also has a ring singularity at its centre rather than a single point singularity.

The other half of the 2020 Nobel Prize in physics was awarded to Reinhard Genzel and Andrea Ghez for their astronomical observations over many years, beginning in the 1990s, which established the existence of a supermassive black hole (SMBH) known as Sagittarius A* at the centre of our galaxy.

In 2015 the first gravitational wave signals were detected, emanating from the merger of two black holes,[17] and in 2019 astronomers produced the first ever image of an SMBH at the centre of galaxy M87*, followed in 2022 by a similar image of Sagittarius A* at the centre of the Milky Way.[18]

Despite this progress, black holes remain weird objects and experts cannot agree on what they are or how to describe them properly.[19–21] Being black, we cannot see them against the blackness of interstellar space, and when near to other things they enfold themselves in optical illusions caused by their intense gravitational fields.[22,23] Anything that enters them is lost to both our sight and understanding, yet everything about them seems to agree quite precisely with the mathematics of GRT.

There are some things that experts have agreed on, and to make this discussion succinct I based it on just three of these. First, black holes conserve the energy of everything that goes into making them, so non-rotating black holes can be characterized by their mass.[24] Our sun is used as the standard for measuring the mass of other celestial objects and is called a 'solar mass,' with the symbol $M_{\odot}$. Second, experts agree that the most fundamental description of the simplest black hole is given by Schwarzschild's exact solution to the field equations in GRT. The Schwarzschild radius is considered to be the "proper distance measure" in studies of black holes and their interactions with other celestial bodies,[25] and the astronomy literature contains numerous and repeated references to it.[26,27] And third, Schwarzschild's solution puts all the mass at the centre of the black hole in a single point of infinite density and zero volume (technically called a 'singularity'), and it places an 'event horizon' around the perimeter at a distance called the 'Schwarzschild radius', which is directly proportional to the contained mass.

Black hole theory

We now know from GRT and Schwarzschild's solution to it that black holes are a consequence of the unique relationship that exists between energy and the geometry of 4-dimensional spacetime which holds it in existence. The presence of energy distorts the geometry of spacetime, and the greater the *energy density* the greater the distortion. This distortion is described as 'spacetime curvature' and it can be measured as a 'radius of curvature.' This unique relationship was unknown before Einstein published his GRT in 1915, and its consequences and implications are still being actively investigated today.

GRT can be summarized in the following equation:

$$\mathrm{G} = \frac{8\pi G}{c^4}\mathrm{T}$$

where G describes the geometry of spacetime, G is the Newtonian gravitational constant, c is the speed of light in vacuum, and T describes the energy content of the universe. However, both G and T are complex mathematical functions, so the only people that usually study GRT are expert mathematicians, but others can still follow the logic of the arguments if they are expressed in simple terms as I have tried to do in this article.

The Schwarzschild radius (r_s) can be derived from GRT as follows:

$$r_s = \frac{2GM}{c^2}$$

where G is the gravitational constant, M is the object's mass, and c is the speed of light in vacuum.[28] We can simplify this expression as follows:

$$r_s = aM$$

where a is a constant ($\frac{2G}{c^2}$). This means that there is a simple linear relationship between a black hole's radius and its mass. For example, if the sun were to be squashed down until it collapsed into a black hole, it would have a radius of about 3 km, and if a star that was 10 times the mass of the sun was likewise squashed to the point of collapse, the resulting black hole would have a radius of about 30 km (i.e. 10 times larger).

Most people think of black holes as very dense objects, but this is not necessarily so. The Schwarzschild radius increases as a simple linear function of mass, but the density of the black hole decreases as an inverse cubic function of the radius.[29] It is unfortunately misleading to refer to the 'density' of a black hole, however, because all the mass that goes into the making of it is concentrated (as energy-equivalent) in the central singularity where spacetime curvature becomes infinite, while the perimeter (the event horizon) marks the point of no return for any object that enters it. It is only for the convenience of comparison with other objects that we use the term 'black hole density' and this limitation should

be kept in mind. Whatever the 'density' might be, however, the significance of the Schwarzschild radius always remains the same—it defines the point at which the escape velocity equals the velocity of light. And since nothing can exceed the velocity of light, nothing can escape from a black hole!

How did our universe end up inside a black hole?

To grasp the cosmological implications of black holes we need to examine them on the scale of the whole universe. We don't exactly know how big the universe is, but we do know that our continuously advancing telescope technology is allowing us to see further than ever before, revealing galaxies upon galaxies without any apparent end.[30,31] There is no reason to believe, therefore, that the universe does not continue like this far beyond our visible horizon.

From the expansion of the universe, we can calculate the Hubble radius of the observable universe as being the sphere marked out by the limits of our observational capacity. From this we can then calculate the mass contained within this sphere and the Schwarzschild equation will give us the radius of its event horizon. Recent estimates of the universe's mass range from 1 to 2 × 10^{53} kg,[32,33] and Claude Mercier combined a variety of methods which produced 1.73 × 10^{53} kg; this gives a Schwarzschild radius of 27 billion light years and an age for the universe of 13.65 billion years.[34]

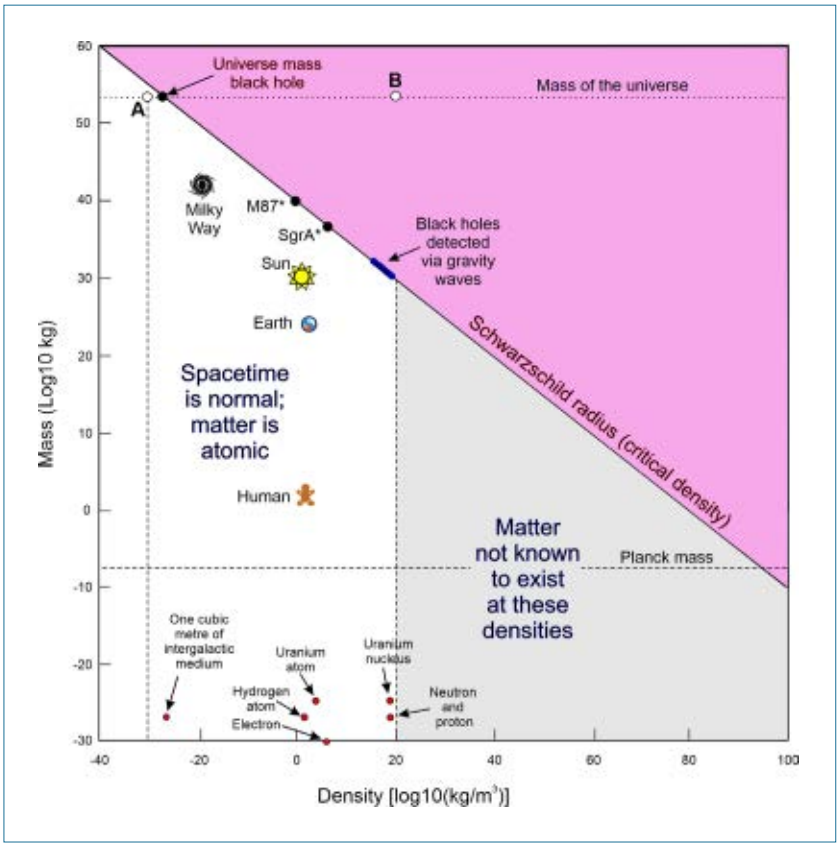

Figure 1. A mass versus density diagram ranging from the smallest to the largest scales in the observable universe. Black holes detected via gravitational waves line up on the diagonal labelled 'Schwarzschild radius (critical density)'; and supermassive black holes M87* and Sagittarius A* are included for comparison. Spacetime is normal and matter is atomic only in the white areas of the graph; areas shaded pink lie beyond event horizons; areas shaded grey are too dense to contain normal atomic matter. The top dotted horizontal line represents the mass of the observable universe (10^{53} kg), which must remain constant in any theory of origin.

Figure 1 puts these numbers into context by plotting mass against density for a selection of observed black holes and extrapolating the Schwarzschild radius line from the smallest- to the largest-known scales. Two well-studied supermassive black holes (M87* and Sagittarius A*) are included to provide extra context. We do not know what a universe-sized black hole would look like (from the inside), so the best we can do is extrapolate what we know about smaller black holes up to the point where the Schwarzschild radius meets the universe's mass.

Only in the white areas of the graph do we find spacetime supporting normal atomic matter. The Milky Way galaxy, the sun, the earth, a human, a cubic metre of intergalactic medium, a single electron, a single neutron (or proton, which has slightly less mass) and a single atom of the smallest naturally occurring element (hydrogen) and the largest (uranium) are included as examples. The pink regions all lie beyond event horizons, and the grey-shaded areas represent an undefined region that would be over-dense because nothing is known to be denser than neutrons, protons, and atomic nuclei.

Everything that we value about life and the universe is made of atoms plus the radiation (e.g. light) that only atomic matter can produce. Atoms consist of very dense nuclei surrounded by varying numbers of shells of electrons, plus lots of 'empty' space.[35] All these things exist only in the white region in figure 1.

The horizontal dotted line at the top of figure 1 represents the mass of the observable universe at 10^{53} kg. The black dot on the diagonal line intersecting it is the black hole equivalent of a universe of this mass. The open circle to the left of it, labelled A, represents a possible universe like ours made of normal atomic matter in normal spacetime. In contrast, the object at position B represents the universe at just above neutron density, which is the 'bounce' point in Black Hole Universe Theory. The lower-down horizontal dashed line,

labelled 'Planck mass', represents the smallest unit of mass defined in Planck units; it appears in theories of quantum gravity and superstring theory, but it is not (yet) relevant to the subject of this article.

Penrose–Hawking black hole expeditions

Stephen Hawking, in his best-selling 1988 book *A Brief History of Time: From the Big Bang to Black Holes*,[36] used a standard method of teaching relativity theory to compare the experiences of two hypothetical observers: one that falls into a black hole, while the other remains a safe distance away. He explained that when a large star uses up its nuclear fuel it collapses to form a black hole, then he continued:

> "Suppose an intrepid astronaut on the surface of the collapsing star, collapsing inward with it, sent a signal every second, according to his watch, to his spaceship orbiting about the star" (p. 87).

The intense gravitational forces would cause time dilation, length contraction, and red shifting of light. The view from the spaceship would see him never actually reaching the event horizon (because of time dilation and length contraction); he would just turn reddish in colour, and progressively dimmer until he faded from view. The astronaut, however, would pass through the event horizon, only to be 'stretched out like spaghetti' and torn apart by the difference in gravitational force between his head and feet!

This would be the case [said Hawking] when considering a stellar-mass black hole, but a happier fate might be possible!

> "However, we believe that there are much larger objects in the universe, like the central regions of galaxies, that can also undergo gravitational collapse to produce black holes; an astronaut on one of those would not be torn apart before the black hole formed. He would not, in fact, feel anything special as he reached the critical radius, and could pass the point of no return without noticing it. However, within just a few hours, as the region continued to collapse, the difference in the gravitational forces on his head and his feet would become so strong that again it would tear him apart" (p. 88).

Roger Penrose went much further and developed a special mapping technique (now called a 'Penrose diagram') which showed that it might be possible for a traveller to pass through the centre of a rotating black hole and emerge into one of several bizarre alternative universes.[37,38]

Many other writers up to the present day have followed Hawking and Penrose in repeating the idea that astronauts might safely enter a black hole (but never return).[23,39–42]

The critical role of the event horizon

Supporters of this Penrose–Hawking theory about humans safely entering an SMBH seem to place their confidence upon little more than the authority of Penrose and Hawking as the award-winning pioneers of our modern understanding of black holes. Everyone agrees that the central singularity is lethal (but perhaps navigable, if Penrose is correct), yet they insist that the event horizon is *not* lethal, so this is what we must examine in more detail.

Wolfgang Rindler (who introduced the term 'event horizon' in 1956) in his 2006 revised textbook entitled *Relativity: Special, General, and Cosmological*, stated that:

> "… nothing very special would occur there … nothing untoward occurs *at* the [event] horizon … this shows the horizon events to be ordinary."[43]

Physicist-philosopher Erik Curiel has used the following thought experiment (based on Rindler, pp. 258–259) to argue that material objects can survive the fall through an event horizon:

> "If all the stars in the Milky Way gradually aggregate towards the galactic center while keeping their proportionate distances from each other, they will all fall within their joint Schwarzschild radius and so form a black hole long before they are forced to collide."[44]

No such celestial event has ever been observed, but something like it might occur when galaxies collide. If a supermassive black hole were to form in this way, a distant observer would see nothing more than an advancing front of darkness (the black hole created by the innermost stars in the collapsing galaxy) as the event horizon grew and engulfed the last star. No one knows how fast the transition to equilibrium takes in a supermassive black hole, but we do know how fast it is in stellar-mass black holes. Two such black holes can merge 'instantaneously' and equilibrate within a few milliseconds,[45,46] while a black hole can 'eat' a neutron star with 'one bite' and reach equilibrium in less than 2 seconds.[47]

No-one knows for sure what happens inside an event horizon, and that is one reason why there is such a diversity of views about them. But we can cut through some of the confusion by focusing on what we do know about how black holes are created.

Black hole creation

The only known way that a black hole can be produced *de novo* is via a core-collapse supernova event of sufficient mass. When a large star burns up all its nuclear fuel and disintegrates in a core-collapse supernova explosion the core may become compressed into one of three known kinds of 'dead star'—a white dwarf, a neutron star, or a black hole. These remnant stages are all 'dead' because their atomic structures have collapsed and can no longer provide thermal resistance against gravity. They are so dense that only quantum fluctuations of subatomic particles provide resistance, and all such resistance disappears in the black hole. Such 'degenerate matter' can only be produced in the hearts of disintegrating large stars and is not known to exist anywhere on Earth or in our solar system.

White dwarf stars exist in a *super-dense* state where only electrons can jiggle about in a very restricted manner among

neutrons and protons to provide enough pressure to prevent further gravitational collapse. Known white dwarf stars have masses in the range of 0.17 to 1.35 $M_\odot$ and densities of about one tonne per cubic centimetre.[48] In neutron stars, electrons are forced to join up with protons to produce neutrons, and nothing but neutrons can jiggle about in an *ultra-dense* state to provide enough pressure to prevent further gravitational collapse. Neutron stars can have masses in the range of 1.4 to 2.35 $M_\odot$, and densities of about a billion tonnes per cubic centimetre. Theoretically, there could also be a 'quark star', which forms when neutrons are crushed even further into quarks and gluons.[49]

In the terminal stage of matter degeneracy—a black hole—the quarks and gluons transmute into energy via Einstein's famous formula $e = mc^2$, where e = energy, m = mass, and c is the velocity of light (~300,000 km/sec). Their energy is conserved in the black hole in the form of the 'infinite curvature of spacetime' at its central 'singularity'. Black holes are not size- or density-limited; the smallest known so far is around 3 $M_\odot$ and the largest known *supermassive* black hole is about 66 billion $M_\odot$.

A core-collapse supernova must produce a vast amount of compression to create a black hole. For a core with the mass of our sun, it would have to be compressed into a volume that is ten thousand trillion times smaller than its original size.[50] And it is this vast amount of compression that causes the structure of atomic matter to collapse well *before* an event horizon forms.

Since we can see nothing inside an event horizon, we must look for answers in the region just outside of it where we *can* make a wide variety of observations. And this is the task that the *Event Horizon Telescope* collaboration has taken up.

The Event Horizon Telescope

The *Event Horizon Telescope* (EHT) is an international collaboration among astronomers in eight different countries using 19 different telescopes that can capture images of black holes using an Earth-sized 'virtual telescope' by integrating images from different locations across the globe. Their first one, published in 2019, looked at the supermassive black hole at the heart of galaxy M87.

This resulted in several important lessons for astrophysicists.[51] Most fundamentally, it clearly demonstrated that event horizons are real and not just 'apparent' (as some theorists claim); also, that they confirm the predictions of Einstein's General Relativity Theory (GRT), and that this one (like most, perhaps) is rotating. Prior estimates of the black hole's mass derived from its gravitational influence on nearby stars ranged from 6.2 to 6.6 billion solar masses, and a more precise figure obtained from this new image came in at 6.5 billion solar masses!

Further work on the supermassive black hole at the centre of our own galaxy, Sagittarius A*, was published in 2022 and

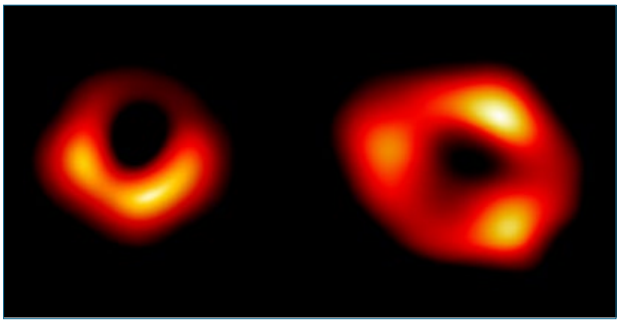

Image (left and right): ESO, Wikimedia / CC BY 4.0

Figure 2. Images of the supermassive black hole in the centre of galaxy M87 (left) and Sagittarius A* in the centre of the Milky Way galaxy (right). Original images from the Event Horizon Telescope website have been passed through a 'hard light' filter to reduce unwanted detail.

came in at 4 million solar masses. Both images are compared in figure 2.

The bright regions in these images represent gas and dust in the accretion rings that is being swept up into the central black holes. The uneven distribution of glowing matter is partly due to the angle of view and partly due to rotation of the central black hole, which drags spacetime around with it. The actual black holes lie within the central dark regions and are surrounded by a distinctive 'shadow region' and a 'photon ring', which further studies have clearly revealed.[52]

Katherine Mack, a theoretical astrophysicist at the Perimeter Institute, has listed four ways a black hole could kill you:

1. *spaghettification*—which is tidal disruption from coming too close to the singularity
2. *fried by accretion disk*—the fiery parts in figure 2 illustrate what happens to *any* material object that comes within gravitational reach, or
3. *zapped by plasma jets* which erupt from both ends of a rotating SMBH
4. *incinerated by firewall*—a theoretical wall of energy that (may) blast out from all over an event horizon.[53]

I am not an expert in any of these fields, so I will not attempt to resolve the matter either way. However, it seems rather obvious to me from figure 1 that everything about life and the universe that we *do* know about exists in 'normal' four-dimensional Minkowski spacetime; it is nearly all made of normal atomic matter, and it produces radiation of various kinds that can only be explained as emanating from known states and energy transitions within normal atomic matter. In contrast, we cannot be sure of anything that lies inside an event horizon except that all its mass is transmuted into energy, which is entirely contained within the singularity at its centre. Importantly, just outside the event horizon of the two SMBHs that we do know about, we *can* see incontrovertible evidence of (i) lethal violence, and (ii) extreme distortion of spacetime. Figure 3 shows three features that next-generation space telescopes should be able to resolve more clearly: (i) the shadow region immediately beyond the event horizon; (ii)

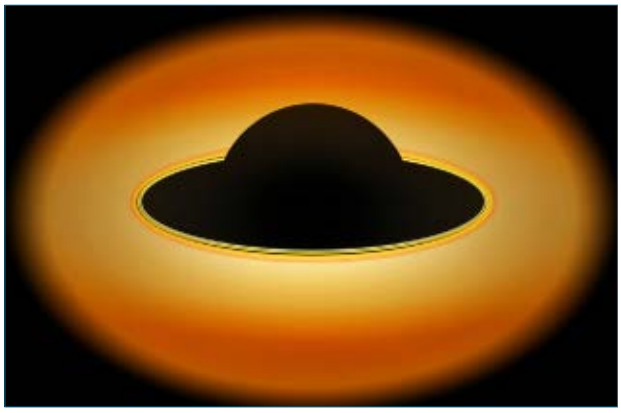

Figure 3. Schematic illustration of structures associated with a rotating supermassive black hole (central black sphere). A shadow region immediately surrounds the black hole, caused by interference effects under extreme spacetime curvature, followed by a series of photon rings resulting from light rays that are trapped into one or more orbits before escaping into the observer's line of sight. The outer orange glow is the accretion disk of compression-heated infalling gas and debris from ruptured celestial objects that came too close to escape. (After figure 12 in Bronzwaer and Falke.[54]).

numerous photon rings at the edge of the shadow; and (iii) a distinction between the outer photon ring and the accretion disk. Nothing about these regions seems to me to be friendly towards visiting astronauts!

Could Einstein have been wrong?

Everything we know about black holes is based upon GRT. Is it possible that Einstein was wrong?

In 1919 Einstein himself addressed this question:

> "The chief attraction of the theory lies in its logical completeness. If a single one of the conclusions drawn from it proves wrong, it must be given up; to modify it without destroying the whole structure seems to be impossible."[55]

He proposed three tests of the theory: the precession of Mercury's orbit around the sun; the gravitational deflection of distant starlight by the sun; the gravitational redshift of light from distant sources. Many physicists since that time have put Einstein's claims to the test, and so far, GRT has passed all of them. Moreover, as technology and instrumentation have improved over the decades, the tests have become more and more stringent and the precision to which GRT still receives the 'pass mark' has advanced greatly.

For example, a recent 16-year study of a double pulsar system has confirmed to unprecedented precision several different predictions of GRT in a strong gravitational field that we were previously unable to test.[56] The effect of gravity on time (time dilation) in the relatively weak gravitational field near the earth's surface has been demonstrated and measured at many different scales; but recently, ultraprecise atomic clock experiments have demonstrated that it still holds true even at microscopic differences in altitude.[57]

Most importantly for the present article, the successful detection of gravity waves emanating from colliding black holes (and neutron stars) proves not just that GRT is correct, but also that Schwarzschild's solution was correct in his 'logically complete' description of the physical nature of the universe. And the awarding of the 2020 Nobel Prize in physics for demonstrating that black holes are a 'robust prediction' of Einstein's GRT would seem to answer the question in the negative—as far as we know today, Einstein was not wrong!

Conclusion

Everyone agrees that black holes are objects in which both variables in the equations of GRT (spacetime geometry, and mass/energy equivalent) have collapsed into a singular point of infinite density and zero volume. But this creates an event horizon at the Schwarzschild radius which prevents us from directly observing what happens inside it, and it is this 'vacuum' in our knowledge that has led to many varied and speculative conjectures.

From a purely physical point of view, figure 1 suggests that the universe we live in exists outside of its 'critical density,' and not inside. Mathematics, however, provides for other possibilities that are not considered here, and those who suggest our universe might be inside a black hole base their confidence on such mathematical considerations.

Alternatively, perhaps this puzzle is just one more enigma in a universe that abounds in mysteries.

According to Prof. Brian Cox, if the universe came into being through a random quantum fluctuation (as many have suggested), then we must choose between the likelihood of (a) it having appeared in a highly ordered primordial state, or (b) it appearing as we see it today in its disordered state. He then said there is an astronomically greater likelihood that it popped into existence as we see it today![4]

A far more reasonable explanation lies in Genesis 1:1, "In the beginning, God created the heavens and the earth."

Acknowledgment

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Milankovitch evidence: strong despite weaknesses in the 1976 'Pacemaker' paper?

Jake Hebert

Recently a geochronologist critiqued my analysis of the 1976 'Pacemaker of the Ice Ages' paper, which purportedly confirmed the Milankovitch Ice Age Theory.[1] My original critique, as well as summaries of it, may be read online.[2-6] This critic graciously gave permission to publish his (anonymous) comments, and interested readers may view them online.[7]

Dating ice ages

Some background information may be helpful. By uniformitarian reckoning, high oxygen isotope ($\delta^{18}O$) values in deep-sea sediments indicate times when global ice volume is greatest. Low $\delta^{18}O$ values in sediments indicate times when global ice volume is minimal. 'In-between' $\delta^{18}O$ sediment values were thought to represent transitions from warm to cold periods. The locations of these 'in-between' $\delta^{18}O$ values are called 'Marine Isotope Stage (MIS) boundaries'.

Shackleton and Opdyke[8] assumed that sediments in the western Pacific deep-sea core V28-238 were deposited at a nearly constant rate. Within the V28-238 core, there was evidence of a magnetic reversal at a depth of 12 m. Potassium-argon dating had already assigned an age of 700 ka to the most recent magnetic reversal, the Brunhes-Matuyama (or B-M) reversal.

With assumed ages of 0 at the top and 700 ka at 12 m depth, and an assumed constant sedimentation rate, it was a simple matter for Shackleton and Opdyke to assign ages to the MIS boundaries in V28-238 (figure 1). Because the V28-238 core ostensibly provided an objective means of dating Pleistocene ice ages, its $\delta^{18}O$ signal was hailed as an 'ice age Rosetta stone'.[9]

Under the assumption that corresponding prominent $\delta^{18}O$ features in different cores are the same age, Hays *et al.*[1] transferred three of the MIS boundary ages from the V28-238 core to the two Southern Indian Ocean cores, the data of which they were analyzing. After setting up tentative timescales for the two cores, their resulting spectral analyses seemed to confirm the Milankovitch theory showing the approximately 100 ka eccentricity, the 41 ka tilt (obliquity), and the 23 ka precession cycles.

In some ways, the 1973 Shackleton and Opdyke paper is even more important than the Hays *et al*. Pacemaker paper[1] itself, because it was the 'foundation' upon which the Pacemaker results rested. It ostensibly showed that climate transitions were occurring at approximately the times expected from the Milankovitch theory. So, it's not too surprising that three years later the spectral analysis of Hays *et al.*[1] seemed to confirm the theory.

Yet the age of the B-M boundary was revised upward to 780 ka in the early 1990s.[10,11] This revision calls into question the original results, even if one completely ignores other potential problems in the paper.[12]

Is the 'Pacemaker' paper unnecessary?

The critic writes,

> "This entire work is misguided. One could completely erase the Hays *et al.* from existence and the observational evidence supporting the existence and nature of Milankovic Cycles would still be overwhelming. For instance, the analysis of Lisiecki & Raymo, discussed in the paper, would emphatically establish the physical reality of Milankovic cycles using a much larger data-set with vastly broader geographical coverage and assessed with much better analytical tools."

I can see how one might think so. Hundreds, if not thousands, of Milankovitch-based papers have been published since 1976. Scientists even use Milankovitch cycles to date sedimentary rhythmites they believe are tens of millions of years old. It is very easy to assume that evidence for the theory simply *must* be abundant. However, despite extensive internet searches, I have only been able to find *three* papers that purport to give objective evidence for the Milankovitch theory. They are Shackleton and Opdyke,[8] Hays *et al.*,[1] and a third paper that I discuss shortly.

The other papers *assume* the Milankovitch theory to be true. Many of these are 'orbital tuning' papers, in which the Milankovitch theory is assumed correct and used to assign ages to $\delta^{18}O$ values in other sediment cores and ice cores. This is the case for the 2005 Lisiecki and Raymo paper the critic mentions. Lisiecki and Raymo themselves state: "We also present a new LR04 age model for the Pliocene–Pleistocene derived from *tuning* the $\delta^{18}O$ stack to a simple ice model based on 21 June insolation at 65°N [emphasis added]."[13] Lisiecki and Raymo do not confirm the Milankovitch theory, they *assume* it to be true. As an aside, Lisiecki and Raymo's allusion to 21 June solar insolation at 65° N latitude brings to mind a fundamental problem with the Milankovitch mechanism. In their time series

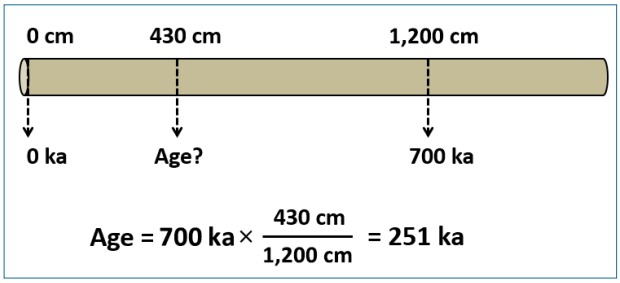

Figure 1. Shackleton and Opdyke[8] used simple fractions to assign ages to MIS boundaries within the V28-238 sediment core. Hays *et al.*[1] transferred three of these ages to the two Indian Ocean cores they used in their analysis.

analyses, scientists often correlate solar insolation on 21 June at 65°N with paleoclimate variables. The 20% modulation in this insolation signal makes the mechanism seem very strong. However, when using 65° N solar insolation for the warmest six months (rather than just June 21), the variation is only about 3–4%. And when other latitudes are included, the variation is even less.[14] Variations in summer solar insolation simply aren't large enough, in and of themselves, to cause major climate change. This is the reason many scientists are convinced strong positive feedbacks can amplify these small inputs to cause repeated ice age cycles.[15,16] This has led them to conclude that our climate is highly sensitive, even to small changes. This belief in 'climate instability' has led them to advocate drastic action to fight 'climate change'.

But if evidence for the Milankovitch theory is lacking, as I claim, this argument for an unstable climate falls apart, and orbital tuning is nothing but circular reasoning!

The Pacemaker paper, 40 years after its publication, was still being celebrated in the journals *Science* and *Nature*.[17,18] If other papers provided strong evidence for the theory, one would think that *Nature* and *Science* would be celebrating those other papers, not the Pacemaker paper.

A telling incident

Paleoceanographers seem to have inadvertently acknowledged this in the mid-1990s. In 1996, geoscientist Wallace S. Broecker arranged a private meeting of oceanographers to discuss criticisms of the Milankovitch theory that physicist Richard Muller (of UC Berkeley) and geophysicist Gordon MacDonald were making. Muller and MacDonald were not advocating a total abandonment of the theory, but a refinement to it, particularly in regard to the cause of the inferred 100,000-year climate cycle. A 1997 *Science News* article described the meeting this way:

> "Muller scored the most points at the meeting when he attacked a standard technique, called tuning, that oceanographers used for dating layers in sediment cores. The task of dating these strata is difficult because sediments may accumulate more quickly during some eras and more slowly in others. To tell the age of layers between known benchmarks, researchers often use the Milankovitch orbital cycles to tune the sediment record: They assume that ice volume should vary with the orbital cycles, then line up the wiggles in the sediment record with ups and downs in the astronomical record.
>
> "'This whole tuning procedure, which is used extensively, has elements of circular reasoning in it,' says Muller. He argues that tuning can artificially make the sediment record support the Milankovitch theory. Muller's criticisms hit home with many researchers. 'He scared the [expletive] out of them, and they deserved it,' says Broecker."[19]

So, what was said at this private conference that so alarmed these scientists? And why did Broecker say, "they deserved it"? Apparently, the charge of circular reasoning *really* hit home. But using orbital tuning is only circular reasoning if evidence for the Milankovitch theory is lacking.

Did someone mention the revised age of the B-M magnetic reversal at this meeting? I don't know, I wasn't there. And to be fair, the *Science News* article does not mention the B-M reversal. But as the proverbial 'elephant in the room', it *should* have been discussed. Shackleton and Opdyke's original methodology along with the revised age of 780 ka causes the timing of climate transitions to be *badly* out-of-sync with Milankovitch expectations (table 1).[5,8]

In any case, a year after this meeting Dr Maureen Raymo published a paper purporting to provide objective evidence that Pleistocene ice ages were occurring at the times expected from the Milankovitch theory.[20] In the very next sentence, this *Science News* article makes it clear that Raymo's paper was a direct response to the charge of circular reasoning in orbital tuning:

> "Oceanographers soon rose to the challenge. In the August *Paleoceanography*, Maureen E. Raymo of Massachusetts Institute of Technology presents an untuned sediment record that corroborates the ice age dates determined by dating."[19,21]

Something was said at this meeting that caused Raymo to feel the need to obtain such 'corroboration'. *But wait!* Didn't Shackleton and Opdyke already confirm that climate transitions occurred at the approximate times predicted by Milankovitch theory (table 1)? Yes, but this was when the accepted age of the B-M reversal boundary was 700 ka, not 780 ka.

That Raymo apparently felt the need to do this is a strong indication that in 1996 she was unaware of additional convincing evidence for the theory. In the previous two decades, a 'long file drawer' of Milankovitch papers had been published.[22] She and the scientists at Broecker's meeting were surely well-acquainted with those papers. If they thought some other paper provided convincing evidence for the theory, there would have been no need for Raymo to publish her 1997 paper.

This is why I think additional evidence for the theory was lacking in 1996, and I don't think the situation has changed since then, given my inability to find other such 'corroborating' papers.

Independent confirmation?

The critic says that radioisotope dating generally agrees with the Milankovitch theory. However, this is an oversimplification. The radiometrically-dated Devil's Hole, Nevada chronology has long presented a cause-and-effect problem for the theory.[23,24]

The critic states:

> "Corresponding isotopic analyses of oxygen and hydrogen in ice cores similarly confirms the chronology of the Milankovic theory. The ice core results can be checked using radiometric dating, ice layer counts and tephra layers in the ice cross-checked against the corresponding volcanic events."

Despite popular perception, ages for deep ice cores do not independently confirm the Milankovitch theory. Rather, the theory is used to correct and constrain these ice core ages. This is especially true for the deep ice cores from East Antarctica, which are dated by theoretical age models.[25] These models implicitly assume long ages by ignoring the time for the ice sheet to form.[26] And the Milankovitch theory is used to 'calibrate' those models:

> "The h and f_b values [age model parameters] are chosen so as to assign well-established ages to two characteristic features in the δ [ice core] record: 11.5 kyr for the end of the Younger Dryas event[1,12] and 110 kyr for the marine isotope stage (MIS) 5d[4], which appears at depths of 1,624 m and 2,788 m, respectively, in the δ record. [footnotes in original]"[27]

> "… we have applied the orbital tuning approach to derive an age-depth relation for the Vostok ice core, which is consistent with the SPECMAP marine time scale. A second age-depth relation for Vostok was obtained by correlating the ice isotope content with estimates of sea surface temperature from Southern Ocean core MD 88-770."[28]

Even in the deep Greenland ice cores, supposedly dated by 'simple' layer counting, the Milankovitch theory ensures that layer counts give the expected answers. An initial layer count in the GISP2 ice core assigned an age of 85 ka to ice at a depth of 2,800 m. However, this contradicted an expected age of 110 ka coming from orbital tuning of seafloor sediments. So, scientists did a recount at higher resolution and—voilà!—they got the 'right answer'![29] The counting process is subjective and counts may be 'adjusted' to agree with pre-conceived expectations.

Poor logic on my part?

The critic then states:

> "The author's argument that the timing of Termination II is inconsistent with Milankovic Theory and thus contradicts it relies on the implicit assumption that Milankovic forcing is responsible for all warming events. This assumption is simply false. Just like we don't invoke Milankovic Theory to explain the end of the Younger Dryas, there is no reason to reject the possibility that some other phenomenon initiated the earliest stages of Termination II. The author's syllogism is based on a false dichotomy and simply invalid."

No one is claiming that uniformitarians attribute *all* climate change to Milankovitch forcing. At issue is the *evidence* for the Milankovitch theory. Because the V28-238 core was ostensibly an 'ice age Rosetta stone', it provided a means of testing the Milankovitch theory. Shackleton and Opdyke's use of the B-M reversal in the V28-238 core to date climate transitions *made*

Table 1. An assumed age of 700 ka for the Matuyama-Brunhes magnetic reversal boundary yields age estimates (third column) for 'Marine Isotope Stage boundaries' that are in reasonable agreement with 'tuned' ages (fourth column) based on Milankovitch expectations, at least for the twelve most recent MIS boundaries (in bold). However, the new age estimate of 780 ka for this reversal causes many of the new age estimates (fifth column) to be tens of thousands of years older than they should be according to expectations derived from Milankovitch theory.

Boundary	Depth in V28-238 (cm)	Old Age (ka)	Tuned Age (ka)	New Age (ka)
MIS 1–2	**22**	**13**	**14**	**14**
MIS 2–3	**55**	**32**	**29**	**36**
MIS 3–4	**110**	**64**	**57**	**72**
MIS 4–5	**128**	**75**	**71**	**83**
MIS 5–6	**220**	**128**	**130**	**143**
MIS 6–7	**335**	**195**	**191**	**218**
MIS 7–8	**430**	**251**	**243**	**280**
MIS 8–9	**510**	**298**	**300**	**332**
MIS 9–10	**595**	**347**	**337**	**387**
MIS 10–11	**630**	**368**	**374**	**410**
MIS 11–12	**755**	**440**	**424**	**491**
MIS 12–13	**810**	**473**	**478**	**527**
MIS 13–14	860	502	533	559
MIS 14–15	930	543	563	605
MIS 15–16	1,015	592	621	660
MIS 16–17	1,075	627	676	699
MIS 17–18	1,110	648	712	722
MIS 18–19	1,180	688	761	767
MIS 19–20	1,210	706	790	787
MIS 20–21	1,250	729	814	813
MIS 21–22	1,340	782	866	871

no assumptions (at least not explicitly) about what was *causing* the climate transitions; it merely *assigned ages to them*. Do these ages (and the implied climate frequencies) agree with Milankovitch expectations? When one uses an age of 700 ka for the B-M reversal, there is fairly good agreement, but when one uses *the exact same methodology* and the revised age of 780 ka, there is not (table 1).

Why hasn't the theory been falsified?

If paleoceanographers *really believe* that the V28-238 core is an objective standard against which to test the Milankovitch theory, an 'ice age Rosetta stone' if you will, why hasn't the revised age for the B-M reversal falsified the Milankovitch theory? Using the revised age of 780 ka for the B-M reversal, the theory now fails *the exact same test* that supposedly confirmed it in 1976. Why has the theory not been abandoned?

I think the reason is obvious. Some scientists are simply in love with the Milankovitch theory. They believe it regardless of whether or not there is any evidence for it. But the general public has been led to believe that evidence for the theory is robust. This is especially troubling when one realizes that the assumption of Milankovitch climate forcing is one of the main arguments that Earth's climate is unstable and that we need drastic action to fight 'climate change'![30]

Why the age revision?

The age of the B-M reversal was revised to 730 ka c. 1979.[31] This new age of 730 ka was supposedly confirmed by several orbital tuning studies.[32–34] By itself, that revision may have not been enough to cause problems for Hays *et al.*[1] However, a 1982 orbital tuning study suggested the age of the B-M reversal should be 790 ka.[35]

In the early 1990s, scientists were 'tuning' other sediment cores near the Galápagos Islands and in the Mediterranean.[10,11] Apparently, they had difficulty doing so with the then-accepted ages for the three most recent magnetic reversals. Hence, they recommended revising the age of these reversals upward 5–7%.[10] This raised the age of the B-M reversal to 780 ka, enough to invalidate the original results.

Rather than simply admitting they couldn't reconcile all the data with the theory, some scientists arbitrarily overruled the K-Ar date for the B-M reversal so it would 'fit' climate signals tuned to the Milankovitch theory. But in doing so they undermined the original argument for the theory. And without that original argument, orbital tuning is nothing but circular reasoning. One author noted this age revision was accepted after 'initial controversy'.[36] It's not hard to see why. Anyone aware that the original Pacemaker results depended *critically* on an age of 700 ka for the B-M *should* have objected. And I'm sure radiometric dating specialists weren't too happy that Milankovitch enthusiasts over-ruled their age of 730 ka for the B-M boundary!

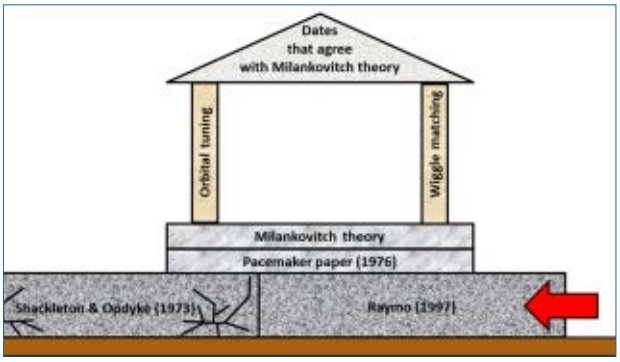

Figure 2. The revised age of 780 ka for the Matuyama-Brunhes magnetic reversal boundary 'cracked' the foundation upon which the Pacemaker results rested by invalidating Shackleton and Opdyke's published ages for Marine Isotope Stage (MIS) boundaries. Was Raymo (1997) an attempt to provide an 'alternate' justification for MIS ages that would still agree with Milankovitch expectations, so that the Pacemaker results could still be seen as valid?

Radiometric confirmation?

Yes, radiometric dating later 'confirmed' the adjusted age of 780 ka,[37] but even the confirmation is not that impressive. To obtain the revised age of 730 ka, a mathematical algorithm searched for an age between 450 and 1,050 ka that gave the best overall age 'fit' to many K-Ar dates for volcanic rocks on either side of the B-M reversal boundary.[31] In 1992 this same technique was used, but using Ar-Ar measurements and additional data. Depending on which data were used and excluded, the age of the B-M boundary was either 755 ka or 780 ka.[37] The authors used the higher age estimate, as they believed it to be more reliable. But this revision was made *after* Hilgen and Shackleton et al. had already suggested that the higher age of 780 ka was 'needed'.[10,11] Was the Milankovitch 'tail' wagging the radioisotope 'dog'?

Conclusion

I have become increasingly convinced that Raymo[20] is now quietly serving as a 'replacement' for Shackleton and Opdyke,[8] so that paleoclimate scientists can still claim that the Hays *et al.*[1] results confirm the Milankovitch theory (figure 2). But would an objective outsider (even a uniformitarian one) consider Raymo's belated confirmation of ice age dates (21 years after the fact!) to be convincing?

It is telling that Raymo didn't use the V28-238 core in her 1997 paper. She used only untuned cores in her analysis,[20] which makes sense, since an objective test of the Milankovitch theory requires untuned data. And the V28-238 core had indeed been orbitally tuned years earlier. However, nothing was preventing her from 'untuning' the V28-238 data and using Shackleton and Opdyke's method and the revised age of 780 ka to obtain revised dates for the MIS boundaries. And since the V28-238 sediments were supposedly deposited at a constant rate, it seems like a 'no brainer' that she *should* have

used it. Strangely, she *did* include the nearby V28-239 core in her analysis, located near the V28-238 core on the Solomon Plateau, but not the V28-238 core itself. Now that the V28-238 'ice age Rosetta stone' no longer confirms Milankovitch expectations, it has apparently outlived its usefulness.[38]

Please understand that I am not accusing Raymo and others of deliberate falsehood. We all have biases, myself included. But sometimes our biases can blind us to circular reasoning.

Space permits me to only respond to this critic's most substantive objections, but I have elsewhere discussed other serious problems with the Hays *et al.* paper.[1,5,12] Nothing this critic has written makes me think my analysis of the situation is incorrect. Readers may compare my response to those criticisms and decide for themselves.[7]

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"The deeps congealed in the heart of the sea"—linguistic investigation of the Red Sea miracle

Gavin Cox

How did the Israelites cross the Red Sea? Cecil B. DeMille's enduring Hollywood vision of seas parting, towering, churning walls of water, Jews crossing safely, and drowned Egyptians is indelibly seared into our cultural memory. God, in His omnipotence, could have caused the waters to defy gravity, but does the Bible indicate that? This article explores the vocabulary of the Red Sea crossing in Moses' poetic *Song of the Sea* (esp. Exodus 15:8) and compares it to Exodus 14's narrative. A Hebrew analysis reveals: God solidified the water, bottom to top, while simultaneously drying the sea bed (even melting a corridor) by a strong east wind. The vocabulary suggests freezing ice, although God, in His omniscience, could have used an entirely unknown process. After Israel crossed, the sea returned, drowning Pharaoh's army. Such startling imagery was artfully described by Moses. Similar ideas were held by the earliest Jewish exegetes.

The Song of the Sea (Exodus 15), composed by Moses, describes the miracle of the Red Sea crossing by the children of Israel. It is the poetic version of the prose account, narrated in Exodus 14. Both accounts complement each other in their details of the Sea's parting, Israel's crossing, and the drowning of Pharaoh's army. This article investigates specific vocabulary in both accounts that describes the miraculous effects exhibited upon the water by God, which caused the sea to part for the Children of Israel and close for Pharaoh's army, drowning them in the depths. This study will concentrate on an analysis of the Hebrew vocabulary in Exodus 15:8 and 14:21–31.

Grammatical analysis of Exodus 15:8

The Hebrew poetry of Exodus 15:8 reads:

8 וּבְרֽוּחַ אַפֶּ֙יךָ֙ נֶֽעֶרְמ֣וּ מַ֔יִם נִצְּב֥וּ כְמוֹ־נֵ֖ד נֹזְלִ֑ים קָפְא֥וּ תְהֹמֹ֖ת בְּלֶב־יָֽם׃

The English Standard Version translates:

> "At the blast of your nostrils (A) the waters piled up; the floods stood up in a heap (B); the deeps congealed (C) in the heart of the sea (D)" (Exodus 15:8).

The vocabulary[1] will be analyzed as four clauses (A–D) (table 1) and compared to the prose account in Exodus 14. It is hoped that a fuller picture of the miraculous intervention by God can be gleaned.

When comparing Clause A with the Exodus 14 narrative account, the common vocabulary is רוּחַ (rûªḥ) 'breath, wind, spirit' (Exodus 15:8; 14:21). Here, 'wind' played a significant part in the miracle's mechanics. The source of the wind is anthropomorphically attributed to God—from his 'nostrils' (with a secondary meaning of 'anger', which Moses' poem likely alludes to in YHWH's judgment of Pharaoh's army). Although not a literal description, it implies the wind was directed in a miraculous way. The prose account states:

> "Then Moses stretched out his hand over the sea, and the Lord drove [וַיּוֹלֶךְ] the sea back by a strong east wind [רוּחַ] all night and made the sea dry land, and the waters were divided [וַיִּבָּקְעוּ]" (Exodus 14:21).

YHWH was the first cause in driving the sea back: וַיּוֹלֶךְ (yôleḵ, hiphil verb, 'to lead, bring'). His agent, a 'strong east wind', implies a geographical origin from (Saudi) Arabia. Being hot, it resulted in drying the freshly exposed sea bed, enabling the Israelites to cross. However, the vocabulary does not support the secular 'wind set-down' theory, that occurs over shallow bodies of water.[2] A further aspect of the wind's work will be discussed later.

Scripture records that it took 'all night' for the waters to 'divide'. The Hebrew is וַיִּבָּקְעוּ (wayyibbāqʿû); a niphal (conjugation) verb meaning 'to be cleft'. TWOT explains this word:

> "This root with its derivatives appears seventy-three times in the OT. Cognates are found in Ugaritic (bq´), Arabic (faqa´a) and Ethiopic. The basic idea seems to be 'a strenuous cleaving of recalcitrant materials' (Greenfeld, HUCA). As a result of the cleaving, the contents may 'burst forth' (cf. Isa 58:8; etc.), but it is clear that this meaning is secondary and not primary ... ."[3]

Table 1. Grammatical analysis of Exodus 15:8, clauses A–B

#	Heb.	Root	Translit.	Grammatical construction	Translation
A	וּ בְּ רִוּחַ אַפֶּיךָ	— — רוח אַף	û bə rûʰḥ ʾappeʸḵā	Particle construction Particle preposition Noun common feminine singular construct Noun common masculine dual construct suffix Second person masculine singular homonym II	And, so, then, when, or, but, that In, at, by, with, among Breath, wind, spirit 1) Also, yea, 2) Nostril, nose, face, anger
B	נֶעֶרְמוּ מַיִם נִצְּבוּ כְּמוֹ־ נֵד נֹזְלִים	ערם מי נצב כְּ נדד נזל	neʿermû mayim niṣṣəḇû ḵəmô- nēḏ nōzlîm	Verb niphal perfect 3rd person common plural homonym I Noun common masculine plural absolute Verb niphal perfect 3rd person common plural homonym I Particle preposition Noun common masculine singular absolute Noun common masculine plural absolute	To be heaped up Water(s) To stand Like, as, when A heap, dam Trickle, drop down, flow
C	קָפְאוּ תְהֹמֹת	קפא תהם	qāp̄ʾû ṯəhōmōṯ	Verb qal perfect 3rd person common plural Noun common both plural absolute	To condense, congeal, become rigid Deep, sea, abyss
D	בְּ לֶב־ יָם	— לב יָם	bə leḇ- yām	Particle preposition Noun common masculine construct Noun common masculine singular absolute	In, at, by, with, among Inner man, mind, will, heart Sea

TWOT discusses the following occurrences, in 30 verses, listed under 5 categories (with an additional 6th) which are listed below (table 2).

Table 2 discussion

TWOT notes that "bāqʿ is used in five situations, all of which express the forcefulness of the splitting action." 1) Locates the splitting actions as coming from within, 2) Expresses the splitting actions encountered in daily life, 3) References to the earth splitting, 4) Associated with warfare and violence, 5) Associated with water and creation. (TWOT adds a 6th category, including the 'cloven' shekel and 'divided' plain/valley). The instances occurring with water are of particular relevance. Psalm 74:15 refers to a spring breaking open* (see table 2), likely referring to the rock from which the waters gush, rather than the waters themselves. Proverbs 3:20 and Genesis 7:11 refer to the 'Tehom'* breaking up, from which the floodwaters surge, which, like Proverbs 3:20, likely refers to the earth as the broken container storing the waters. Exodus 14:16; Psalm 78:13; and Isaiah 63:12 refer to the splitting of the Red Sea*.

The only clear instance of bāqʿû referring to water is at the accounts of the Red Sea crossing (Exodus 14:16, narrative; Psalm 78:13, poetic; Isaiah 63:12, prophetic). But what of other words meaning 'to divide' that are applied to water? Table 3 lists them all.[4]

Table 3 discussion

Table 3 lists 7 different Hebrew words for 'dividing' (typically of solids) which are also applied to water. It is noteworthy that in all three Red Sea passages (of different genres) the same word for 'dividing' (bāqʿû) is used, when 7 other verbs could suffice. This implies that the 'cleaving' of the Red Sea is thought of as qualitatively distinct, compared to other OT examples describing dividing water. The question needs to be asked, in what way does bāqʿû relate to water, when used typically for solid materials, for example, breaking through walls or splitting wood? This will be treated more fully later.

Clause B

> "… the waters piled up; the floods stood up in a heap …"

Clause B describes, with startling imagery, the behaviour of the water. The niphil perfect verb נֶעֶרְמוּ (neʿermû) means 'to be heaped up', and describes the action done on the water. The root of נֶעֶרְמוּ (neʿermû) occurs in a word meaning 'heap' (solid materials) (עֲרֵמָה), for instance of 'grain',[5] 'offerings', or 'rubbish'.[6] The following niphil perfect verb נִצְּבוּ (niṣṣəḇû) describes additional action performed on the water, making it 'to stand'. Finally, the floods (flowing waters) נֹזְלִים (nōzlîm) are described as being 'as/like' כְּמוֹ (ḵəmô) a 'heap' (nēḏ).

The nearest analogy to this clause is found in Joshua 3:16, describing Israel's Jordan crossing. Here, the text

Table 2. Instances of bāqʿû in TWOT with context (items* are further discussed)

Reference	Context	Genre	Comment	TWOT#	Solid
Gen 7:11	God's works in the Flood	Narrative	'Tehom' split open	5	yes*
22:3	Abraham and Isaac sacrifice	Narrative	Split wood for sacrifice	2	yes
24:22	Abram's servant offers gifts	Narrative	Half-shekel weight	6	yes
Exo 14:16	God divided Red Sea	Narrative	Israel passes through Red Sea	5	?*
38:26	Materials for Tabernacle	Narrative	Half-shekel weight	6	yes
Num 16:31	Ground splits	Narrative	Korah's rebellion	3	yes
Jos 9:4, 13	Gibeonites trick Joshua	Narrative	Old leather wineskins are torn	1	yes
I Sam 6:14	Ark travels to Bethshemesh	Narrative	Split wood for sacrifice	2	yes
I Kin 1:40	Anointing of Solomon	Narrative	Metaphor for earth-splitting noise	3	yes
II Kin 8:12	Horrors of war	Narrative	Women with child 'ripped open'	4	yes
15:16	Horrors of war	Narrative	Women with child 'ripped open'	4	yes
25:4	Babylon's siege of Jerusalem	Narrative	City wall broken through	4	yes
II Chr 21:17	Judah routed under Jehoram	Narrative	Palace broken into	4	yes
25:12	Horrors of war	Narrative	Children dashed to pieces	4	yes
Psa 74:15	God's works in nature	Poetic	Water springs broken open	5	yes*
78:13	God divided Red Sea	Poetic	Israel passes through Red Sea	5	?*
141:7	Psalm of David	Poetic	Earth broken by ploughing	2	yes
Pro 3:20	God's works in Creation	Poetic	'Tehom' split open	5	yes*
Isa 34:15	Isaiah's prophetic symbolism	Prophetic	Breaking snake egg shell symbolism	1	yes
40:4	Isaiah's prophetic symbolism	Prophetic	New valleys created	6	yes
48:21	God refreshes Israel	Prophetic	Rock split to release water	5	yes
58:8	Isaiah's prophetic symbolism	Prophetic	Light 'breaks forth'	1	no
59:5	Isaiah's prophetic symbolism	Prophetic	Breaking snake egg shell symbolism	1	yes
63:12	God divided Red Sea	Prophetic	Israel passes through Red Sea	5	?*
Eze 30:16	Destruction of Egyptian cities	Prophetic	Thebes city destroyed	4	yes
Amo 1:13	Horrors of war	Prophetic	Women with child 'ripped open'	4	yes
Mic 1:4	Day of the Lord	Prophetic	Valleys will split	3	yes
Zec 12:11	Judgement of Jerusalem	Prophetic	Valley (lit. split place)	6	yes
14:4	Day of the Lord	Prophetic	Mount of Olives split	3	yes

Table 3. Vocabulary used for 'dividing' applied to water

Ref.	Heb.	Translit.	Translation	Context	Genre	Comment
Gen 1:6	בדל	bdîl	Separate, divide	Creation	Narrative	Separating waters
Gen 1:9	קָוּוּ	qāwû	To be collected	Creation	Narrative	Separating seas
Gen 2:10	פרד	pārēḏ	Divide, separate	Eden	Narrative	4 rivers separate
Jos 3:16 ff	כרת	krâṯû	To be cut off	Jordan	Narrative	Israel crosses
II Kin 2:8, 14	חצה	ḥāṣû	Divide	Jordan	Narrative	Elijah crosses
Psa 114:3	יִסֹּב לְאָחוֹר	yissōḇ lə'āḥôr	To surround, Back, rear, behind	Jordan	poetic	Israel crosses

Table 4. 4 instances of qāp̄'û

Ref.	Heb.	Translit.	Translation	Verb construction	Date
Job 10:10	תַּקְפִּיאֵנִי	taqpî'ēnî	To curdle, coagulate	Verb hiphil imperfect 2nd person masculine singular suffix 1st person common singular	Pre-2000 BC[10]
Exo 15:8	קָפְאוּ	qāp̄'û	Congealed	Verb qal perfect 3rd person common plural	1446 BC
Zep 1:12	קֹפְאִים	qqō̤p̄'îm	Settled	Verb qal participle masculine plural absolute	640–609 BC
Zec 14:6	יִקְפָּאוֹן; וְקִפְאוֹן	yəqippā'ôn; wəqippā'ō̤n	To condense; To condense	Verb qal imperfect 3rd person masculine plural paragogic nun kethib; Noun common masculine singular absolute qenre	520–518 BC

describes what appears to be a land-slip at Adam (likely Tell ed-Damiyeh) causing Jordan's waters to form a dam behind the 'heap'.[7] Jordan's water 'rose up' קָמוּ (qāmû) (particle adverb directional heh homonym) אֶחָד ('eḥāḏ) (numeral cardinal masculine absolute) 'one, another'; [against] a 'heap' נֵד (nēḏ) [of earth]. However, the qualitative difference is that the Red Sea's waters become 'as/like' a heap (i.e. self-supporting), suggesting the sea solidified (Clause C), either by freezing or an unknown miraculous process.

Psalm 33:10 also refers to waters 'like' (כַּ) a 'heap' (nēḏ), which clearly references the Genesis 1:10 creation of 'gathered seas'. The context being, not standing heaps of water, but divinely directed gathering together.

Clause C

…. the deeps (t^{e}hôm) congealed (qāp̄'û) …"

According to TWOT (2495a) תְּהוֹם (t^{e}hôm) 'deep, depths, deep places' occurs thirty-five times in the OT. In Genesis 1:2, t^{e}hôm occurs first to describe the unformed earth, then in Genesis 7:11; 8:2 t^{e}hôm refers to the floodwaters' source. The evidence from Clause C's vocabulary indicates the depths, possibly arising from beneath the earth[8]/sea floor, demonstrating the magnitude of the miracle (see Clause D).

qāp̄'û: an extraordinary word

The word translated 'congealed' in English is a rare Hebrew verb קָפְאוּ (qāp̄'û), which is qal perfect, meaning 'to congeal, become rigid'. What complicates matters for translators are the associated complex verb constructions (table 3). Just three OT verses contain this word:

1. Zephaniah 1:12 describes corrupt men who are 'settled [qō̤p̄'îm, (qal absolute)] on their lees', a metaphor relating to over-fermented wine, where settling sediment (lees) thickens wine to the point of ruin.
2. In Zechariah 14:6, qāp̄'û occurs within a highly complex verb construction used to describe action upon light and/or atmospheric conditions. Here, English translations offer a variety of alternatives, demonstrating the difficulty of the clause.[9]
3. In Job 10:10, qāp̄'û refers to 'thickening (curdling) of cheese'; a metaphor describing God forming Job in the womb.

Table 4 lists all passages containing qāp̄'û, their associated verb construction, translation, and generally accepted date of composition.

Clines adds 'contract, be reduced' (Zechariah 14:6); 'curdle, coagulate' (Job 10:10); and 'foam' (Exodus 15:8), and a 'curse term' from Qumran Scroll (4QapMes 5.2$_{13}$), as

well as 'frozen' and 'frost'.[11] As can be seen, the word qāp̄ʾû is used in varying, complex ways, to describe the 'thickening' of substances: wine, atmospheric conditions / light(?), cheese, and water. Wine and cheese thickening involves protein coagulation, but in what way is water 'thickened'? The following discussion addresses this question.

Greek Septuagint evidence

The Septuagint (LXX) Greek translation of the first five books of the Hebrew Bible (Torah/Pentateuch), occurred c. mid-3rd century BC.[12] It is instructive to know how biblical Hebrew vocabulary was comprehended. The translation of qāp̄ʾû in Exodus 15:8 is informative:

> "καὶ διὰ πνεύματος τοῦ θυμοῦ σου διέστη τὸ ὕδωρ ἐπάγη ὡσεὶ τεῖχος τὰ ὕδατα ἐπάγη τὰ κύματα ἐν μέσῳ τῆς θαλάσσης."[13]

The English translation (LXE) by Brenton[14] states:

> "And by the breath of thine anger the water parted asunder; the waters were congealed as a wall; the waves were congealed in the midst of the sea."

The *Liddell-Scott Greek Lexicon*[15] lists ἐπάγη under πήγνυμι (LSGL-34484). A closely related root word (LSGL-34486) πηγυλίς means 'frozen, icy-cold'.

This verb also appears in LXX Job 6:16, which mentions: 'κρύσταλλος πεπηγώς', i.e. 'congealed ice.'[14]

However, ἐπάγη appears in Lamentations 4:10 to refer to 'skin cleaving (congealing) to bones'. Job 10:10 uses ἐτύρωσας meaning 'to curdle, to coagulate'[16], used here of cheese. The LXX 'paraphrase' of Zephaniah 1:12 does not use a word for congeal. It can be concluded that ἐπάγη (πεπηγώς) *can be* used of ice, but also of congealed skin. So, not conclusive in determining how the LXX scribes understood Hebrew qāp̄ʾû.

An extra-biblical occurrence of qāp̄ʾû

The Book of Sirach, or *Ecclesiasticus*, originally written in Hebrew, is considered the largest example of wisdom literature (similar to Proverbs) to have survived from antiquity (c. 200–175 BC). *Sirach* was written by the Judahite scribe (Yeshua) Ben Sira(ch) of Jerusalem (figure 1). In Egypt, it was translated into Greek by Ben Sira's anonymous grandson, who added a prologue.

Sirach 43:20 uses qāp̄ʾû in relation to water. The commentary and Hebrew translation by Schechter and Taylor (1899) is enlightening, revealing the translational challenges of this verse. The passage describes God's works in nature, specifically seen through weather events. Verse 20 deals with the cold, which, in Hebrew, states[17]:

> 20 עינת רוח צפון ישיב וכרקב יקפיא מקורו:
> 20c על כל מעמר מים יקרים וכשריון ילבש מקוה:

> "The cold of the north wind he causeth to blow, and congealeth [qāp̄ʾû] his spring (marg. [inal note] the pond) ... . Over every standing water he spreadeth a crust, and a pond putteth on as it were a breastplate."[18]

The Greek text of these verses states:

> "ψυχρὸς ἄνεμος βορέης πνεύσει, καί παγήσεται [frozen] κρύσταλλος [crystal] ἐφ' ὕδατος ἐπί πᾶσαν συναγωγὴν ὕδατος [καταλύσει καί ὡς θώρακα ἐνδύσεται τὸ ὕδωρ]."[19]

Schechter and Taylor explain:

> "The Greek states the fact that ice is formed in cold weather; but the context seems to [require] a simile, to stand in parallelism with כשריון 'as it were a breastplate.' … Ice on water [is] being compared in the next line to a breastplate …"[20]

A modern Hebrew translation by Wright is more understandable:

> "A cold north wind will blow, and ice will freeze [qāp̄ʾû] on water; upon every gathering of water, it will settle, and like a breastplate the water will put it on."[21]

Image: Julius Schnorr von Carolsfeld (1794–1872), Wikimedia / Public Domain

Figure 1. (Yeshua) Ben Sira(ch) teaching Tora, 1860 woodcut by Julius Schnorr von Carolsfeld.

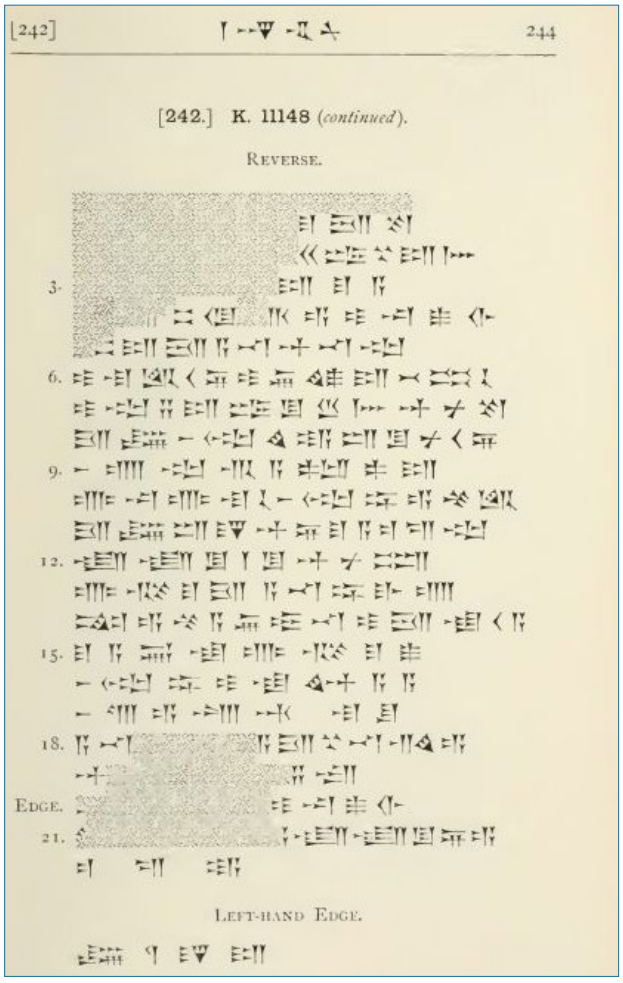

Image: Harper, R.F., Assyrian and Babylonian Letters, Vol 3, University of Chicago Press, London, p. 243, 1896.

Figure 2. Cuneiform tablet K. 11148 (242)

In *Sirach* the Hebrew verb qāp̄ʾû is being used to mean 'frozen', and the water had become 'ice' which furnishes the metaphor of a covering 'breastplate'.

Further evidence is to be found in modern Hebrew dictionaries, where qāp̄ʾû is understood as 'frozen, congealed' (e.g. *The Oxford English–Hebrew Dictionary*[22] and *NTC's Hebrew and English Dictionary*).[23] Furthermore, modern Greek–English dictionaries translate παγος as 'ice', where the root for παγώνω means 'frozen' (e.g. *Oxford New Greek Dictionary*)[24] and παγήσεται is understood as 'frozen, congealed' (*Collins English–Greek Dictionary*).[25] It can be concluded that by c. 200 BC qāp̄ʾû was understood as 'frozen'/'ice' when applied to water.

A likely cognate of qāp̄ʾû in Neo-Assyrian

Evidence from Neo-Assyrian seems to suggest a cognate word. Here, a near phonetically identical word, kuppû, means 'snow, ice' (CAD 8, 551).[26] For instance, cuneiform tablet K. 11148 (242) (figure 2)[27] (dated 798/797 BC)[28] from Ashurbanipal's library in Kuyunjik, Nineveh, uses kuppû to describe ice and cold. Harper translates:

> Line 10 transliteration: *issu pan ku-up-pi* …
> Translation: "I abandoned … the chariot which went with me on account of the ice."

> Line 11 transliteration: *ku-up-pu dāna addaniš* …
> Translation: "The King knows the cold is very severe."

Neo-Assyrian (spoken between 10th–7th century BC) is an Akkadian branch (along with Babylonian) of the East Semitic language.[29] Although a direct etymological link between (Semitic) Hebrew qāp̄ʾû and (Semitic) Neo-Assyrian kuppû, meaning 'ice', cannot be proved here, the comparison is nonetheless instructive.[30]

Bible commentaries and qāp̄ʾû

Cross and Freedman state:

"The meaning of the verb is difficult to determine. … The principal meaning of the word, so far as it may be interpreted from other OT contexts, seems to be 'congeal' or 'coagulate'. We may suppose an earlier meaning 'churn', 'ferment', or 'work', from which the later meanings were derived. With respect to milk, 'to churn', and 'to coagulate' or in the case of wine, 'to ferment' and 'to thicken' are not long jumps in thought. In the present context the former idea, involving action, is preferable."[31]

Cassuto, in his commentary of Exodus 18, states:

"And at the blast of Thy nostrils—by the east wind that Thou didst cause to blow—the waters piled up—that is, hyperbolically, the waters stood like a heap on both sides; the floods stood up in a heap [נד nedh]—the waters, which are naturally fluid, stood firm as though they were a heap, a mound of earth (*nadd* in Arabic), or as if the deeps congealed in the heart of the sea—as though the waters of the deeps in the midst of the sea were turned to solid ice. By means of these miracles, the Lord brought retribution upon the wicked according to their wickedness."[32]

Boyle, in her analysis of Exodus 15, states:

"Fascination with the phenomenon/miracle expressed in the verb qp[a] [qāp̄ʾû] dominates scholarly attention to the verse about activity in the heart of the sea (Exod. 15:8). Controversy persists over its meaning, whether 'congeal' or antithetically 'churn', The translation 'churn' honors the motion of the sea, while 'congeal' (AV, RSV) is a scientific anachronism."[33]

Boyle argues that qāp̄ʾû cannot mean 'freezing' because the ancient Israelites didn't have a modern, scientific understanding of thermodynamics, or hydrogeology, so "would not have known the phenomenon as freezing." Furthermore, she denies that the use of qāp̄ʾû in Exodus 15:8 means 'freeze' because of its varying usage in Job, Zephaniah, and Zechariah:

> "The freezing of water and the curdling or sedimentation of other liquids … are very different processes … . The biblical appropriation of the same verb to designate these very dissimilar processes betrays a superficial observation of liquids thickening or hardening. Even the concept of solidification is too sophisticated, for it involves 'a complex interplay of many physical effects', beyond the ken of ancient poets."[34]

Boyle's condescending rhetoric does no justice to Moses, who was "educated in all the wisdom of the Egyptians" (Acts 7:22). However, such knowledge is certainly not 'beyond the ken' of the divine author of Exodus and the mind behind the miracle.

W.H.C. Propp states:

> "… despite some ambiguities, the translation 'congeal, solidify' fits all occurrences. … In Exod. 15:8, too, 'congeal' fits well."[35]

Propp goes on to state:

> "… Yahweh freezes the Sea (… v. 8 'congealed'). If so, the reference to Yahweh's burning anger in v 7 becomes more appropriate. Yahweh's first blast turns the Deeps to ice. His second (v. 10) melts the gelid [icy] waters."[36]
>
> "… The poet has been developing a progressively paradoxical and miraculous image: the waters are first piled up (neᶜermû), not unusual in a storm, but then they actually stand upright, (nissaḇû)! How? Because some of the waters, the 'Deeps', have congealed, presumably into ice … ."[35]

As can be seen, commentators grapple with this verb and offer diverse opinions.

Ice in Job

Job is an ancient (possibly pre-Abrahamic)[37] book of wisdom literature which contains many examples of natural imagery declaring God's wonders in creation. Specific to this discussion are references to ice, frost, and snow. Here, Job describes how the surface of the ocean is turned to ice, in what appears to be a reference to the post-Flood Ice Age[38]:

> "From whose womb did the ice (qā́raḥ) come forth, and who has given birth to the frost (ḵəp̄ōr) of heaven? The waters become hard like stone, and the face of the deep (ṯəhôm) is frozen (lakkā́ḏ)" (Job 38:29–30).

Here, the Hebrew word קֶרַח (qā́raḥ) refers to 'ice' (cf. Job 6:15; Psalm 147:17) and כְּפוֹר (ḵəp̄ōr) 'frost'.[39] The Hebrew verb לכד (lakkā́ḏ) is hithpael imperfect, typically translated 'capture' or 'overthrow', and is here uniquely translated 'frozen'.[40] In Job 37:10 מוּצָק (mûṣāq), 'narrowing' is used in the sense of broad areas of water being constricted by forming ice. 'Snow', שֶׁלֶג (šā́leḡ) also occurs in Job.[41]

Of particular interest to this discussion, two words from Job (snow and frost) occur in Exodus. At Exodus 4 Aaron and Moses performed miracles before Pharaoh's court, including the sign of the leprous hand (v. 6) described as being 'leprous like snow' (šā́leḡ) (cf. Numbers 12:10). 'Frost' (ḵəp̄ōr) is used to describe the appearance of manna on the ground (Exodus 16:14). Both the leprous hand and manna are being compared to freezing phenomena that must have been familiar to the Israelites and Egyptians at the time of the Exodus. It should be noted that frost is a near analogy to ice, being frozen water, albeit on a micro-scale, and ḵəp̄ōr is phonetically and semantically analogous to qāp̄ʾû, suggesting a linguistic link. However, qāp̄ʾû in Job is translated 'congeal/coagulation' (Job 10:10), specifically for cheese, whereas Job uses other terms for 'ice' and 'frozen'. Furthermore, the 7th plague (Exodus 9:18–34) involved ice, i.e. 'hail' בָּרָד (bārāḏ) mixed with 'fire' (i.e. lightning). The root ברד means 'cold'. Therefore, the Egyptians and Hebrews had become familiarized with ice and freezing phenomena by this time.

Linguistic origins of qāp̄ʾû

Jewish tradition[42] holds Moses was the editor/redactor of Job, specifically during Moses' 40-year exile in Midian.[43] Qāp̄ʾû appears first in Job 10:10 as a word to mean 'congeal', and Job probably pre-dates Exodus. However, Job contains words for 'ice' and 'freeze' that Moses could have used in Exodus 15:8, but didn't. This leads to the possibility that qāp̄ʾû does not mean 'freeze', in terms of ice. However, Moses could have re-emphasized qāp̄ʾû to refer to 'freezing of ice', but from where did he derive this meaning? If Moses did not use this word from Job, could he have used vocabulary inherited from Canaan via Jacob? A survey of the language of Canaan (West Semitic) reveals the word qrh (cf. Akkadian qarāḫu), meaning 'to freeze, to become frosted', and qrḥ (cf. Akkadian qarḫu) meaning 'frozen', and qrš 'to freeze, to be(come) a solid mass'.[44] However, these words are too far removed phonetically to represent borrowed vocabulary. Moses likely knew Hittite, where the root word 'eka' appears in words for 'cold, ice, frost, frozen'; however, 'eka' is not phonetically related to qāp̄ʾû.[45] Could Moses have utilized an Egyptian word? A possibility lends itself: 'qbb', which means to be 'cool, cold, refreshing, icy'

Table 5. List of possible cognate, or phonetically and semantically related ANE vocabulary

Reference	Translit.	Translation	Language	Date
Exo 15:8	qāp̄ˀû	Congeal, freeze	Biblical and modern Hebrew	c. 1446 BC
Exo 16:14	kəp̄ōr	Frost	Biblical Hebrew	c. 2000 BC (?)
Cuneiform tablet K. 11148	ḵuppû	Ice	Neo-Assyrian	798/797 BC
Wb 5, 22.5–23.20	qbb	Cool, cold, refreshing, icy	Middle Egyptian	c. 1200 BC

(Wb 5, 22.5–23.20). This evidence will be investigated fully in part 2. Table 5 lists four semantically and phonetically similar ANE words that theoretically offer cognates for Hebrew qāp̄ˀû.

At this stage it is still unclear as to how Yahweh solidified the water from the biblical linguistic evidence provided by qāp̄ˀû.

Clause D

"… in the heart of the sea."

The poetic use of 'heart' (leḇ) mirrors the idea of Clause C's 'depths' (ṯəhōm) of the sea (yām). Both clauses, C and D, have implications for where the Israelites crossed, as the vocabulary indicates the larger scale approach.[46]

Walls of water

Exodus 14:22 states:

"And the people of Israel went into the midst of the sea on dry ground, the waters being a wall (חוֹמָה) to them on their right hand and on their left" (cf. 29).

The Hebrew word חוֹמָה (ḥōmāʰ) 'wall' occurs first at Exodus 14:22, then 69 times in the OT (a common word). The context of succeeding occurrences determines its meaning. Table 6 lists the first five earliest occurrences of ḥōmāʰ (excluding Exodus), along with their English translations.

'Wall' (ḥōmāʰ) in these verses clearly refers to solid structures. The question is, how does ḥōmāʰ refer to other kinds of non-sold barriers? Table 7 lists all occurrences.

Table 6. First five occurrences of texts using ḥōmāʰ

Reference	Translation of text using ḥōmāʰ	Genre
Lev 25:29	"If a man sells a dwelling house in a walled city …" (cf. vs 30–31).	Narrative
Deu 3:5	"All these were cities fortified with high walls …"	Narrative
Jos 2:15	"… [Rahab's] house was built into the city wall, so that she lived in the wall."	Narrative
Jos 6:20	"… the people shouted a great shout, and the wall fell down flat."	Narrative
2 Sam 11:20	"Did you not know that they would shoot from the wall?"	Narrative

Table 7. Five occurrences of 'metaphorical' texts using ḥōmāʰ

Reference	Translation of text using ḥōmāʰ	Genre
1 Sam 25:16	"They [David's men] were a wall to us both by night and by day …"	Narrative
Prov 18:11	"A rich man's wealth is his strong city, and like a high wall in his imagination."	Wisdom
Sol 8:9	"If she is a wall, we will build on her a battlement of silver …" (cf. vs. 10).	Poetry
Isa 30:13	"… therefore this iniquity shall be to you like a breach in a high wall."	Prophecy
Lam 2:8	"The LORD determined to lay in ruins the wall of the daughter of Zion."	Poetry

These texts demonstrate ḥōmāh can be used metaphorically. For instance, David's men acted as a 'protective barrier' in I Samuel 25:16, a narrative text. The two occurrences in Exodus 14 (narrative) refer to walls, but those made of water. The remaining 62 occurrences of ḥōmāh refer to solid structures. The evidence that the water in Exodus 15:8 had become solidified (qāp̄ʾû), either by some unknown miraculous process or frozen, makes sense of an otherwise mysterious verse.[47]

Earliest Jewish commentary on Exodus 15:8

Philo of Alexandria, also Philo Judaeus (c. 20 BC–c. AD 50) (figure 3), was a Hellenistic Jewish philosopher who lived in Alexandria, a Roman province of Egypt. He wrote Greek commentaries based on the Hebrew Bible. In his commentary of the *Life of Moses* (2:253), he stated of the Red Sea crossing:

> "The sea was broken asunder, each portion retired back, there was a consolidation of the waves along each broken-off fragment throughout the whole breadth and depth, so that the waves stood up like the strongest walls; and there was a straight line cut of a road thus miraculously made, which was a path for the Hebrews between the congealed waters … ."[48]

Here the Greek used by Philo, translated 'congealed', is 'κρυσταλλωθέντων' (*krystallôthenton*), which literally means 'crystallized'[49] (figure 4).

Rabbi Yishmael ben Elisha Nachmani wrote the *Mekhilta*, the earliest known (c. 100–135 AD) halakhic midrash (Jewish commentary) on extracts of Exodus (figure 5). He described the miracles performed by God at the Red Sea crossing:

> "The sea was broken through and made like a vault … . It was piled up into stacks … . It formed a sort of a heap [נד]… . The sea congealed [קפאו] on both sides and became a sort of glass crystal [זכוכית של בולוס] … ."

Although both Philo and R. Yishmael wrote centuries after the Red Sea miracle, their writings are consistent with the Bible's vocabulary, and likely reflect ancient Jewish traditions (figure 5). Yahweh solidified the Red Sea, which may have included the idea of freezing ice (figure 6).

Conclusion

Key poetic vocabulary in Exodus 15:8, compared with narrative vocabulary in Exodus 14:21–22, 27–29 has been considered. It was found that the Hebrew verb (qāp̄ʾû), translated 'congealed', in context, can refer to freezing ice or other solidifying effects. Later Hebrew literature (*Sirach*, c. 200–175 BC) and modern Hebrew suggests freezing ice. Neo-Assyrian kuppû (798/797 BC) and Middle Egyptian

Image: André Thévet (1502–1509), Wikimedia / Public Domain

Figure 3. Philo of Alexandria, imaginative illustration by André Thevet (1584), French portrait artist.

Image: Didier Descouens, Wikimedia / CC BY-SA 4.0

Figure 4. Philo used Greek 'κρυσταλλωθέντων' (*krystallôthenton*) for 'congeal', literally 'crystallized'.

Image: Adolf Behrman (1876–1942), Wikimedia / Public Domain

Figure 5. Painting of Talmud readers by Adolf Behrman (1876–1942)

Image: Simon Berger, Pexels.com / CC0

Figure 6. Heaped up crystal-like shards of sea ice

Figure 7. Israel crossing the Red Sea—composite illustration with *Exodus from Egypt* (1907) by the Providence Lithograph Company, in the foreground.

qbb (19th Dynasty) carry the meanings of 'snow, ice'; 'cool, refreshing, cold, icy' representing possible cognate words. Freezing makes sense of the description of the sea being 'split open' (bāqʿû), a word typically reserved for solid, resistant materials. Also, 'walls' of water, where Hebrew (ḥōmāʰ) typically refers to solid structures throughout the OT. If freezing is correct, then thermal expansion of the ice likely buckled the sea surface, thrusting up shards of broken ice, referred to as 'standing' (niṣṣəḇû) 'heaps' (néʿermû), although this is only a possible interpretation. Wind (rûᵃḥ) played an essential part in the miracle, whereby a (hot) easterly wind blew all night, thereby drying the seabed, enabling Israel's crossing. If freezing ice was involved, the wind would have melted a glassy corridor (cf. Philo's *krystallôthenton*). After this, God broke the walls (possibly by thawing), causing the sea, dammed behind, to drown the Egyptians. Earliest Jewish exegetes Philo Judaeus (c. 20 BC–c. 50 AD) and Rabbi Yishmael (c. 100–135 AD), basing their studies on the biblical Hebrew, drew similar descriptive conclusions. Yahweh may have used a freeze–thaw cycle to accomplish this miracle of saving the Israelites and drowning the Egyptians. However, the original biblical verb qāp̄ʾû, meaning 'freezing', is not conclusive. What can be said is that, by divine means, unknowable to human minds, God 'solidified' the sea for Israel and returned it to water for the Egyptians, thereby drowning them—a striking visualization of the miracle, based upon the implications of the Hebrew text. It represents a radically different vision than that popularized by Cecil B. DeMille's *The Ten Commandments*, whereby watery 'walls' defy gravity (cf. figure 7 composite image). Part 2 will look at the Egyptian religious and linguistic aspects of the Red Sea crossing.

Acknowledgments

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The extreme rarity of long-lived people in the post-Flood era

Robert Carter

The post-Flood patriarchs had extended lifespans, yet scant evidence exists for extremely old people in the archaeological record. There is a simple mathematical reason for this discrepancy: their extreme rarity in the exponentially growing post-Flood population. The post-Flood decrease in lifespan follows a clear mathematical progression. It should be possible, therefore, to estimate the spectrum of expected lifespans in the population as it grew. A population model was created that assigned maximum ages to each person based on the average number of generational steps between them and Noah. An actuarial death rate table was used to induce mortality each year, and population growth was controlled with prespecified life history patterns (e.g. year of maturation, number of years between children, and age of menopause). In the end, it was shown that long-lived people were numerically overwhelmed by shorter-lived people in nearly all scenarios. Part of this was due to the rapid buildup of individuals with the maximum number of generational steps from Noah. The oldest children in a family generally have children before their younger siblings. Thus, the lifespans of the average person in the population quickly drops even as long-lived people continue to have children. In the model presented here, there is also a clear difference between *potential* lifespan and *realized* lifespan. This solves several riddles, both in archaeology and in Scripture.

Genesis chapters 5 and 11 contain a list of names that trace descent from Adam to Noah and from Arphaxad to Terah, respectively. By linking additional data, one can build a chronogenealogy[1] that spans the Flood year, giving us a complete chronology from Adam to Abraham, then forward in time at least to King Manasseh of Judah.[2] Lifespans were steady in the antediluvian world (Genesis 5), averaging 857 years (± 57 SD) from Adam to Noah (excluding Enoch). After the Flood, lifespans decreased precipitously, reaching the modern average after a few dozen generations. Thus, the earliest periods in human history should include evidence for people who were much older than the modern average lifespan. Such evidence has not been found in the archaeological record. This discrepancy has caused, alternately, defenses[3] and rejections[4] of the straightforward biblical claims.

Consider the famous passage where Jacob met the Egyptian pharaoh. He was asked but one question, "How old are you?" (Genesis 47:8). Jacob was 130 at the time, but the question attains significant relevance when you realize that Jacob's grandfather, Abraham, had visited Egypt fully 200 years earlier (Genesis 12:10–20). Yet, since a pharaoh is generally the scion of a long line of oldest sons, perhaps 10 generations had happened in his family tree over that same 200 years. Jacob was an aberration in Pharaoh's world. In fact, long-lived people would have been beyond the experience of nearly all ancient people, even during the time when the Bible says they still walked the earth.

One can add additional people to the list of post-Flood lifespans by pulling in multiple data points from outside the Genesis 11 chronogenealogy. Doing so creates a list of 32 people, spanning up to 38 generations (e.g. Noah through to Manasseh),[5] all of whom are reported to have died natural deaths, but not all of whom are in the direct line of descent from Noah to Jesus. By fitting a curve to the lifespan data, one sees that each generation lives less than the previous generation, in a clear mathematical relationship (figure 1). Here, I am taking the data in a straightforward manner, assuming no generational gaps[6] and no stylistic,[7] spiritualistic,[8] or symbolic[9] numbering schemes. The data outside Genesis 11 fit the exponential decay curve almost precisely, so there is little reason to not take it at face value. The alternative explanation, that an ancient scribe modified the lifespans of random people scattered throughout the several scrolls that made up the Old Testament canon, to get them to follow some geometric progression, can be safely discounted.

And yet, the scriptural data represent a one-off experiment. There is no replication and there is considerable 'scatter' about the regression line in figure 1. Stochasticity is expected when so few data points are involved, forcing us to adopt mathematical approximations. Assuming the regression in figure 1 is a good approximation for the decline in lifespan per generation (using 'birth year' on the x-axis produces a worse fit than using 'generation'), one can begin to make assumptions about lifespans in the general population.

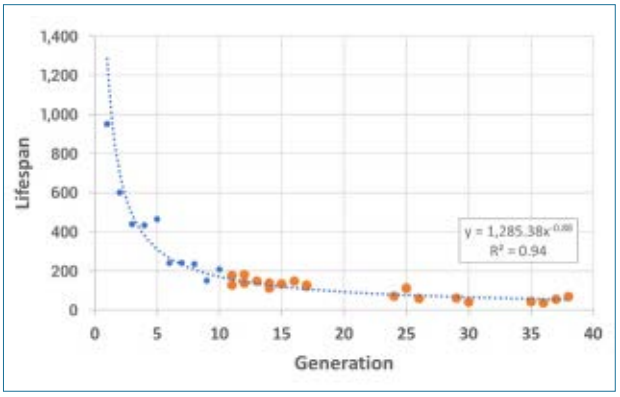

Figure 1. Lifespan vs number of generations from Noah for various biblical figures. Included are all biblical figures for whom we have a death age and a clear genealogy. Blue dots = data from Genesis 11. Orange dots = data outside Genesis 11. The terminal person is King Manasseh of Judah. See table 1 in Carter (2021)[2] for additional details.

Table 1. Time to reach various population sizes in a population using default parameters

Population size	Years to reach
100	69
1,000	137
10,000	203
100,000	271
1,000,000	339

Using a well-established population model,[10–13] this study attempts to quantify the spectrum of lifespans as it unfolded over time in the post-Flood world. This directly addresses, and answers, questions about the lack of long-lived people in the archaeological record.

Methods

The population model of Carter (2019)[13] was modified to track the number of generational steps between each individual and Noah. Since any given individual can trace back to Noah along multiple pathways of various lengths, and since the greatest effect on an enhanced lifespan would be from the shortest pathway, the average minimum number of generations for the father (gen_f) and mother (gen_m) were used to calculate that of the child. The regression in figure 1 was used to assign to each individual a maximum lifespan (e.g. $1{,}285.4 \times gen_i^{-0.88}$). Since this formula would produce very short lifespans after many generations, a minimum lifespan of 85 years was applied to each model run. This point was reached at the 22nd generation. During each modelled year, old people were removed from the population first, giving room for new births. Unmarried people who were above the age of maturation (e.g. 20 years) were then paired up at random. Previously married women were then tested to see if enough time had elapsed since their last birth (e.g. 3 years). Births were assigned at random, with a 1/3 probability of a woman giving birth in any given year, up to the age of menopause (e.g. 80% of lifespan). Each of these parameters were adjustable, but these values were used in the experiments reported here.

The next step was to randomly reduce population size according to a modern actuarial life expectancy table.[14] The death probability at each age was scaled according to expected lifespan (scaled age = age × minlifespan/lifespan). But, since long-lived people were subject to this elimination round every year, very few would be able to reach their expected age of death. Thus, to produce biblically relevant results, some way of enhancing their survival was necessary. Three models were explored: 1) no adjustment; 2) the death probability was multiplied by the ratio of age/lifespan, giving long-lived people an added advantage that waned as they aged; 3) the reduction step was skipped at equal intervals to give all people the same number of tests, based on their maximum possible lifespan (e.g. a maximum of 85 tests per individual). The third model was used for all results reported here.

The final step was to reduce the population size at the end of each year to match the maximum allowed size for each model run, if necessary. This was done by randomly removing individuals. Total lifespan was not factored into this final step, meaning any individual was as likely to be eliminated. Allowing the population to grow to a large size (e.g. 1,000,000) gave more time for the Patriarchs and Matriarchs to live before they were subjected to this random reduction process, but even this did not hold it back for long since all populations grew quickly.

Results

Population size increased quickly in all model runs (table 1). Once attaining the maximum population size, 2% to 3% of the population had to be randomly culled at the end of each year. This was after people who had reached their maximum lifespan had been removed and after the actuarial life expectancy curve was applied to the population. Running models with larger population sizes (e.g. 1,000,000 individuals) did not significantly affect any of the results reported here, but they took much more time to run to completion, so what follows is a summary of population models with 100,000 individuals. In all population models,

the age distribution quickly took on the expected appearance (figure 2).

In terms of generations, the population took on a similar overlapping generation spectrum as seen earlier.[9] Over time, variability in the minimum number of generational steps between the people in the model and Noah increased. For example, at year 1,000 in the default population model, a handful of people could be as few as 15 generations or as much as 33 generations from Noah.

The model produced reasonable results for changing lifespans over time (figure 3), with individuals often reaching a significant fraction of their maximum lifespan. We can also estimate the fraction of people who lived for any number of years (figure 4). Over the first 1,000 years in one model run, 3.3 million people were born into the population. More than 99% of them died before the age of 90. Only one out of every 100,000 people lived to the age of 300. Put another way, very old people quickly became a vanishingly small proportion of the population over time (figure 5). At model year 100, the six founders (the blue dot at year 200 above the main line in figure 5) lived among a very young but rapidly growing population. By model year 200 (orange line in figure 5), they were still alive but represented a very small fraction of the total.

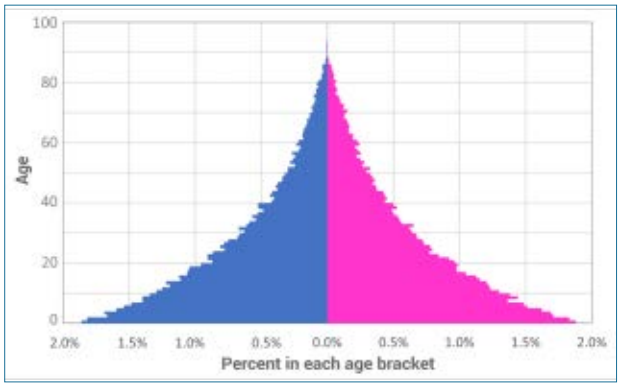

Figure 2. The age distribution at model year 1,000 for a default population of 100,000 individuals. Males are in blue, females in pink.

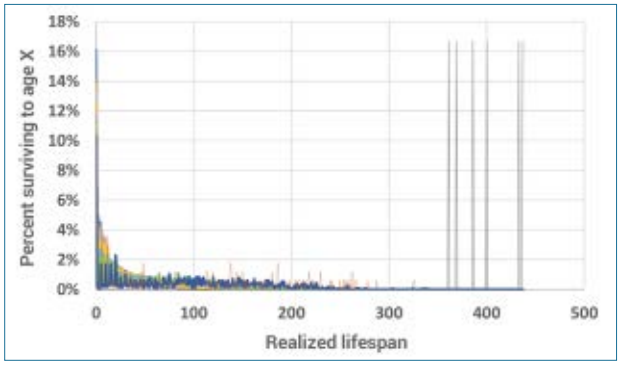

Figure 3. Maximum vs realized lifespans. Each coloured line represents one lifespan cohort. For example, the six founding individuals (tall grey peaks on the right) had a maximum lifespan of 698 years but managed an average lifespan of about 400 years in this model run. Some of their children (blue line) lived long lives but others died much younger.

Discussion

Assigning ages to skeletal remains is not an exact science. After examining hundreds of human cadavers specifically to develop age-dating methods, pathologists have devised several metrics that can be used to estimate age at death. Some are more accurate than others, but it has long been known that it is easier to accurately determine the age of younger people than older people. Children go through dramatic and highly characteristic growth stages, and most (modern) human children follow a life history pattern with little variation in timing. The sexes can be differentiated after puberty, and childbirth can often create visible changes to the pelvic region, but aging of the skeleton is regulated by genetic, epigenetic, and environmental factors.[15] Thus, in isolation, most measures are poor metrics of age. Yet, several aspects of the skeleton (when available) are generally examined, and the results pooled. This includes examination of pubic symphyses (bone fusions in the pelvic region), certain aspects of the ends of the sternal ribs and the auricular (lobed) portion of the ilium, and the degree of fusion in cranial sutures.[16] Tooth wear, bone porosity, and other measures can be included in these assessments. In the end, age-dating skeletons is an art that requires considerable expertise.[17]

It would be very difficult to tell the difference between two skeletons with different rates of maturation. Cuozzo (1994) noted that the teeth of Neanderthal children fossils often display more tooth wear than they should.[18] Although this was controversial within creationist circles, this *could* indicate that Neanderthals developed more slowly than modern humans. If so, modern approaches to age-dating skeletons might not apply to Neanderthals, or indeed to any ancient individual. Considering that ageing is related to development, if a person was destined to live for centuries, perhaps sexual development was also delayed. Delaying puberty by only five years or so would have a major impact on age estimates when people were expected to live for only 40 or 50 years in the ancient world. Thus, there are no modern proxies for biblical lifespans and the question of what we should expect to see in the skeletons of very old people is an open question.

It also must be pointed out that old people don't start out old. Even in a population where some individuals could

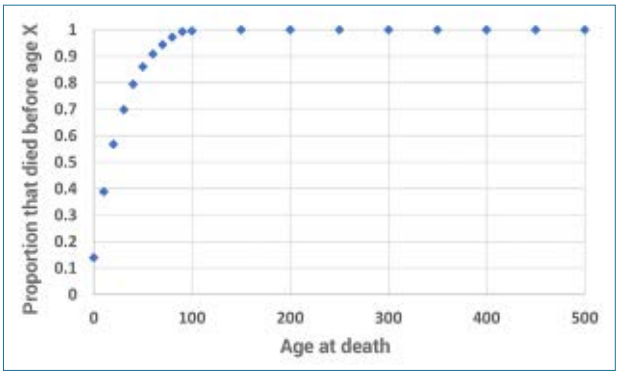

Figure 4. Cumulative distribution of people dying before a given age across 1,000 years in a default population of 100,000 individuals

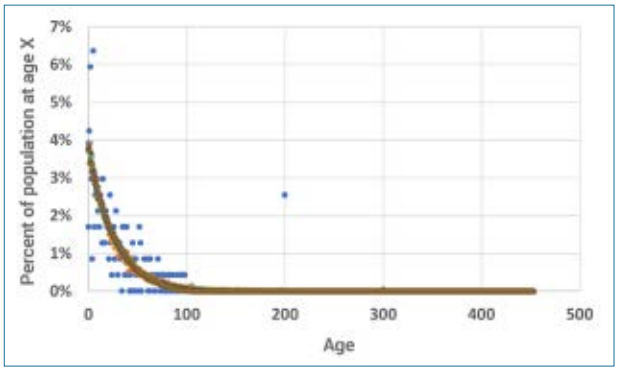

Figure 5. Percent of the population at any given age in a default population of 100,000 individuals. Data were collected at 100-year intervals.

live for centuries, a) they start out at age zero, and b) the population will continue to be dominated by young people as they transition into an above-average lifespan. Because of this, ancient burial sites should be dominated by people who died young.

People must also survive long enough to grow old. Potential age is not the same thing as realized age at death. The famous Neanderthal burials at Krapina showed evidence that the community nurtured injured individuals who survived things like fractured bones. Yet, skull fractures and other evidence of blunt-force trauma to the skull are evident in multiple individuals.[19] Whether the injuries were due to fighting/warfare or simple environmental hazards, they show that the world in which these individuals lived was quite dangerous. It would be unlikely for anyone to live to a great age in such circumstances.

The steady decay of post-Flood lifespans indicates that these are not random deaths caused by disease, warfare, or starvation. Yet, the Bible does not say that the Patriarchs died of old age. The Bible also does not say the listed Patriarchs are the first-born children. There are seven generations in a row (Arphaxad through Nahor) where the named son is born when the father is approximately age 30 (31.4 ± 2.3 SD). This is curious. Are these first-born sons? If so, people were delaying marriage at least a decade longer than the modern average. Alternatively, these could be the oldest legitimate children. Concubinage is quite common among royalty worldwide (e.g. Abraham + Hagar, Jacob + Bilhah and Zilpah, etc.), and the Patriarchs would have been at least chieftains, if not princes or kings, in the post-Flood world. Or perhaps this is simply a genealogy of Abraham and is not intended to be seen as a list of first-born children.

There is something special about Abraham, however. First, he is associated with the Patriarch Eber, who is singled out for special treatment in Genesis 10:21. Abraham is called an Eberite (aka Hebrew) when Lot was captured (Genesis 14:13), immediately prior to the famous Melchizedek passage. Abraham comes from the house of Eber and had some understanding that this was important. Is it possible that Abraham was the scion of a long lineage of first-born sons, tracing back to Eber, or even to Noah? If so, this might explain how the family records came into his possession (I assume that Moses was not inspired to write everything down with no prior written records from which to consult). This might also speak to the events surrounding Abraham and Lot (whom Abraham protected with great care). Instead of Abraham, perhaps Lot was the namesake, having been born of Abraham's older brother? Note that we do not know how old Terah was when Abraham (then Abram) was born, nor do we know the birth order of the three brothers (Abram, Terah, and Nahor). There are several possibilities that fit the biblical data,[4,20] yielding ages from 70 to 180 for the age of Terah at the birth of Abram. Either way, the pattern of 'about 30' is broken with Terah (Genesis 11:26, cf. Genesis 5:32). Why, after so many evenly spaced generations, did Terah suddenly wait until he was over 70 to father the three listed sons? This delay would have added to the paradox of having long-lived people in a population of otherwise short-lived people.

Over time, older siblings have more descendants than younger siblings. There are many examples in the modern world where a woman who is already a grandmother has a child later in life. This makes her grandchildren older than their aunt or uncle. In a world where people are living for centuries, it is entirely feasible for them to have a child at the age of, say, 20, and another at 100. By the time that second child is born, the first could be a great-great-great grandparent with hundreds of living descendants. Thus, mathematically, all populations will eventually become dominated by people with the maximum number of generational steps from the originals. If post-Flood lifespans were tied to generational steps, the world would quickly fill with short-lived people.

Another way to illustrate the dilution of long-lived people in a biblical scenario is to simply make a chart of a

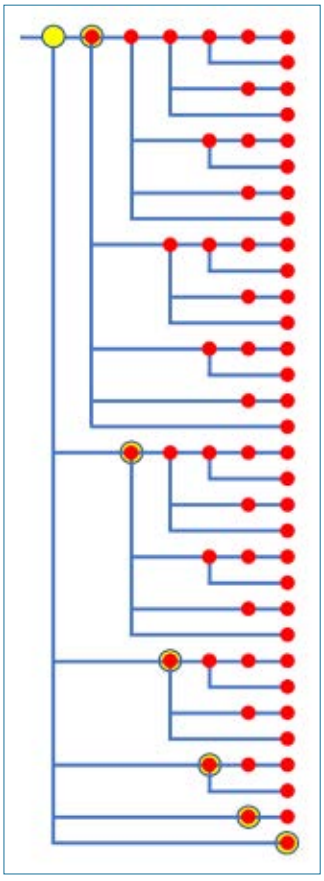

Figure 6. A stylized male-line genealogy of a single man (yellow circle) over time. Each individual has a son at each time step. The starting man has six sons in total, each with a very different number of descendants.

long, stylized genealogy. Consider the scenario in figure 6. Assume this is a paternal tree that only lists fathers and sons. Each man in this tree had a son at each time step. The founding man (indicated by the yellow circle) had six sons in all (indicated by yellow halos). But during this time series, the sons did not have an equal number of descendants. They had, respectively, 31, 15, 7, 3, 1, and 0 descendants. This discrepancy is made even worse when you consider that children are not born in even time increments like this. The delay between birth and an individual's childbearing years is much greater than the average time between children. Younger children are penalized more than this chart indicates. Thus, all populations should be dominated by the descendants of oldest children. If the decrease in post-Flood lifespan was at all linked to generational steps from Noah, this would ensure that lifespans would decrease at the maximum possible rate. In the end, the post-Flood population was saturated with short-lived people, even though long-lived people continued to produce long-lived children for several centuries.

These results are based on multiple simplifying assumptions, so some caution is warranted when drawing conclusions. However, adjusting most of the life history parameters in the model would only exacerbate the stark contrast between long-lived and short-lived people. For example, if the age of maturation was made proportional to lifespan, short-lived people would even more quickly dominate the population. The same would happen if long-lived people spaced children father apart. There is room for further experimentation, and the current results do not give any specific answers, but what is clear is that there should be vanishingly few very old people buried in ancient gravesites.

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The passage of light in the universe—absolute or relative motion?

Clifford Denton

The foundational assumptions of the theory of Special Relativity (SR) bypass the need for a background medium in the universe to carry light. By reconsidering these assumptions, we open the way for a fresh exploration of the passage of light within a fixed frame of reference. We show that the measurement of the speed of light, carried by such a medium, will always give the same result independent of the motion of the observer. The results of SR relating to time dilation and length contraction, seen through a framework of absolute measurements, takes on a new perspective. This enquiry into the way light travels in the universe opens the way to re-examination of all aspects of SR, with the potential to also challenge the wider theory of General Relativity. Thereby, new proposals can be made concerning such things as light from distant stars and the age of the universe.

Background

At the turn of the twentieth century there was a surprising find. Experiments were getting more sophisticated to examine the theory that a light-bearing medium called *the ether* existed. It was considered that accurate measurements of the passage of light to and from a reflector would detect a change in the speed of light, giving evidence that the ether existed. When experiment after experiment seemed to show that at whatever speed a body moved, the speed of light seemed to be independent of the motion, doubt was cast on the idea of an ether pervading all space. The 1881 experiment by Michelson and Morley is well known in this regard.[1]

The Lorentz Transformation Equations were proposed in 1892. They were developed over the next decade as a means of compensating for the paradox of the seeming invariance of the speed of light independent of the motion of a body.[2] The idea that time is a variable depending on velocity was beginning to emerge, even though it was contrary to the accepted creation-based absolute measurement of time relating to the rotation of the earth in relation to the sun.

Albert Einstein resolved the problems that he perceived in the experiments of the time by establishing a theory based on two axioms. One axiom ignored an ether and the other accepted, without further question, that the velocity of light was the same to all observers. This gave way for a new theory that, incorporating the Lorenz equations, led to a new way of looking at the universe.

Einstein's two axioms of special relativity

In his 1905 paper,[3] Einstein wrote, regarding "unsuccessful attempts to detect a motion of the earth relative to the 'light medium'":

1. "*... not only the phenomena of mechanics but also of electrodynamics have no properties that correspond to the concept of absolute rest.*"
2. "*... that light always propagates in empty space with a definite velocity* c *that is independent of the state of motion of the emitting body* [emphases added]."[4]

Axiom (or 'postulate' as Einstein called it) number 1 is a statement that relativity theory will be independent of any fixed frame of reference or ether, whether it exists or not.

Axiom number 2 *assumes* that the universe has an extraordinary property that allows for the velocity of light to always be the same however an observer is moving. This is totally counter-intuitive and gives one the suspicion that it was an error made in seeking a new way forward, to break a deadlock. To illustrate the irrationality of this assumption, consider light from the sun, emitted at 186,000 mi/sec, being intercepted by a spaceship going towards it at 100,000 mi/sec (were it possible). The observer in the spaceship would expect to measure the speed of light arriving at the spaceship as the sum of the two velocities, 286,000 mi/sec. Einstein proposed that we accept that it would always be measured as an invariable value to all travellers as 186,000 mi/sec.

With such an assumption, despite all the physics that has been built on the theory of relativity with seeming success, we are wise to attempt alternative explanations for the results of experiments. Even if we cannot detect an ether, we can continue to examine why the speed of light does not change depending on the motion of a body. Indeed, it is known that Einstein himself went back to a luminiferous ether in 1920.[5]

Time dilation and length contraction

A consequence of following the logic of SR is that time is redefined, giving rise to the result that in moving objects,

time will slow down as clocks move. There is a similar result in General Relativity (GR) where time varies depending on the strength of gravitational pull at a certain point. The slowing of time is called Time Dilation. There does seem to be experimental evidence to support this. We introduce here the constant γ, familiar to SR.

If a body is moving at speed v, and the speed of light is c

$$\gamma^2 = 1 - v^2/c^2.$$

This is the factor by which, in SR, time dilates. Suppose two identical clocks record the same time at a given instant, but one is moving at speed v with respect to the other. An observer who is stationary with the first clock will read a passage of time as t on the stationary clock but γt on the moving clock. This is called 'time dilation', as predicted by the Lorentz equations.

There is a similar result for the contraction of length in a body moving relative to another body. Suppose a body is measured as length L by a stationary observer. If it is then moved at speed v, the stationary observer will measure the body's length as contracted to γL. This length contraction is predicted by the Lorentz equations.

These are well known results of SR, but they are mentioned here because we will take a subtly different approach. We will need to return to this later in this paper but, for now, we will state our assumption, recognizing what is useful from the results of SR.

Measurement of time and shrinkage of length in moving bodies

If there is a material pervading the universe called the ether, we agree that it may never be possible to detect it. Nevertheless, if it is plausible that it exists and is the medium by which light is carried, we must build our hypotheses based on this assumption. In a given location of the universe it can be considered as a fixed frame of reference from which, theoretically, absolute measurements can be taken. This opens the way for much conjecture, as to whether this ether is the material that has been used since creation whereby the Lord stretched out the heavens (Isaiah 40:22) and whether its 'density' varies across the universe. There are things we may never know but our scientific minds will go on making hypotheses. These hypotheses can take new directions if we accept the existence of the ether and of absolute, rather than relative, measurements.

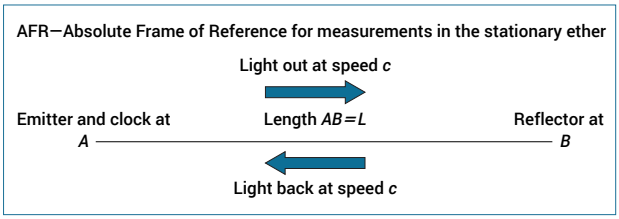
For the discussion that follows, we will propose that the equations for time dilation and length contraction derived by the system of SR are valid but understood in a different way. If a clock moves in the universe, it would move through the ether and thereby be affected by it. It is not unreasonable to propose that the measurement of time on this clock changes by the factor γ as in SR. According to the Lorentz–Einstein equations, the rates of all physical processes, including clock rates, change in a moving body. Similarly, the particles that make up a moving body are affected by motion through the ether in a way that causes lengths to contract, again by the factor γ. This may seem to be the same as SR, but it is not. It is simply that a moving object interacts with the ether, affecting lengths and times due to the motion.[6]

By accepting this as an assumption to be followed up later in the paper, we are in a position to consider the passage of light through the ether, the rest position of which is the frame of reference from which absolute measurements, theoretically, are made.

The velocity of light is constant for all observers, but for a different reason than proposed by SR.

First we must point out that there has been no experiment, nor could there be, that measures the speed of light in one direction. Every measurement of the speed of light is two way, to a reflector and back. We propose that this is the flaw in Einstein's second postulate. He had no way of checking his assumption, so simply created a postulate that had the potential of error. If Einstein's postulate is incorrect, then this affects all the conclusions of SR founded upon it. If we can demonstrate the plausibility of the constancy of a two-way (to reflector and back) 'average' measurement of the velocity of light, we have an explanation for the paradox following the Michelson–Morley experiment. As a result we can build up an alternative to SR, based on absolute measurements.

Let us consider a light signal sent a distance L to a reflector and back as measured by instruments that are at rest with regard to the ether (at rest in an Absolute Frame of Reference (AFR)).

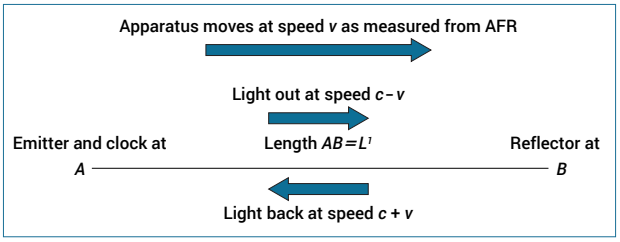


Light is transmitted from A to B a distance of L. There is no motion of measuring instruments at A or of the reflector at B, so there is no adjustment for motion in the Galilean/Newtonian sense of relative motion.[7] Therefore, the time of travel of light from emitter at A to reflector at B and back is the sum of the time outward, L/c, and to the time of the reverse journey, L/c, giving a total time t:

$$t = 2L/c.$$

Now let us consider the situation where the *same apparatus* is moving at speed v, making calculations of time

for the light to go out from the emitter at A to the reflector at B and back.



A clock at A, moving with the apparatus, records the total time for the two-way journey of light from A to B. Since the entire apparatus is moving, the absolute distance between A and B will decrease, due to the motion through the ether, to a length L^1. The calculation of time for the outward and return journey of light, A to B and back, by the principles of Galilean/Newtonian relativity gives:

Time outward A to B $L^1/(c - v)$ *Time back B to A* $L^1/(c + v)$

If we call the absolute total time for the two-way travel of light t^1,

$$t^1 = L^1/(c - v) + L^1/(c + v) = 2cL^1/(c^2 - v^2)$$
$$= 2cL^1/c^2(1 - v^2/c^2) = 2L^1/c(1 - v^2/c^2)$$

We recall that $\gamma^2 = 1 - v^2/c^2$

So we can rewrite the time as $t^1 = 2L^1/\gamma^2 c$.

Now, we have assumed that contraction of length due to motion gives $L^1 = \gamma L$, giving $t^1 = 2\gamma L/\gamma^2 c = 2L/\gamma c$.

We can now calculate the apparent speed of light for the *two-way journey* from A to B and back, as measured by instruments moving at speed v through the AFR.

Considering length, the shrunk length from A to B is $L^1 = \gamma L$ in absolute terms. However, the measuring instrument for length (the 'ruler') is also moving with the apparatus. It shrinks in length by the same proportion as the length AB itself. Though there is shrinkage, this will not be apparent when measured by the instruments in motion. Thus, the length AB, used for calculating the speed of light in the two-way journey, for the instruments in motion, will seem to be L, not γL.

Considering time, t^1, is the absolute time of the two-way journey of light, the time of travel, as measured by the moving clock, which slows by the factor γ due to interaction with the ether, is therefore $\gamma\tau^1 = \gamma\, 2L/\gamma c = 2L/c$.

We can now calculate the speed of light as measured from readings on the moving instruments.

'Average' two-way speed of light, apparent to a moving observer using the moving measuring instruments of length and time, total distance/total time, is:

$$2L/\gamma\, t^1 = 2L/(2L/c) = c.$$

Using measurements based on an absolute frame of reference and assuming that this is the rest position of the ether, we see that whatever the speed of an observer, we always get the same value for c, as it appeared from the experiments of the early 20th century. This re-interprets the postulates of SR, giving us a clearer view of the universe in terms of the Lorentz–Einstein equations.

We note also that this is a measurement of an *averaged two-way journey of light*. Einstein's postulate was that light *in one direction* would remain constant to any observer, and this part of the postulate would have to be reconsidered in the light of our new understanding.

God designed His universe to be based on relationships, not isolation.

We used the result predicted by SR of time dilation and length contraction, rethinking them in absolute terms to be the slowing of clocks in motion through the ether and the actual shrinkage of length due to motion through the ether. We now need to justify this assumption. These are issues that can be investigated further, and the reasoning depends on one's assumed model for matter. Conflicts between SR and quantum mechanics are well known. One tests a theory against another, and this will always be so. When we are dealing with high speeds and minute particles, we only have evidence and not proof, so the search will go on and be limited by the light that can be shed on this by the God who created all.

From our limited knowledge of the design of the constituent elements of matter, we would accept that at the smallest level, beyond the range of microscopes, there are particles of some kind that are in motion with respect to each other. They remain in a solid state due to their interaction with one another. Whatever the construction of the ether, they move through it and are held together by bonding signals that pass between them. This is like the emitter and the reflector of our discussion concerning the speed of light. It could be that all bonding signals, the forces of nature, work in this way, whether by waves or particles or both, including all electromagnetism and gravity. Such speculation opens the way to asking questions and forming hypotheses concerning the nature of both matter and the space between matter, which carries the medium of communication.

It will depend on our model how we seek an explanation of length shrinkage and slowing of clocks due to motion. We imagine bonding signals travelling through the ether between particles and bodies, the two-way motion of which is affected in a similar way to the passage of light from A to B in our discussion of the speed of light. It is reasonable, therefore, to expect adjustment of distance between constituent particles to preserve the harmony of time and distance which bonds the particles together. This will result in a discovery that the constant γ is involved, just as in the above discussion.

Pym and Denton realized that they would need to consider this in their exploration of absolutes, similar to what is outlined in this paper.[8] They could only illustrate a way of thinking through one model; in this case, of photon bonding. Their model did produce the expected result. This, at least, can be an encouragement to others to continue the enquiry based on whatever theory of the material universe they hold. We believe that, starting with the enquiry of the passage of light through the universe, we are free to consider absolute measurements again with confidence, rather than the more complicated measurements leading to SR and GR.

These ideas are not new. In 1895, considering then-existing models, H.A. Lorentz showed that according to Maxwell's equations in an ether, a moving lattice of ions would shrink as it moved through the ether, shrinking by the exact amount that Einstein's theory later showed from different postulates.[9]

Summary

We proposed that the two foundational postulates of Special Relativity be re-interpreted. The alternative view was expressed, that a light-conducting medium in the universe is still a plausible option. The key issue was addressed; namely, to show that the measurement of the speed of light by any observer will always be constant, based on absolute measurements. We discovered that this hypothesis is demonstrable, giving credit for the advances made via SR, which suggest that clocks slow and lengths contract, in our case explicable by use of absolute measurements.

We make all our measurements in a closed universe, using instruments constructed from the matter of the universe. Only by observing from outside the universe could we see completely objectively. This is not our privilege, so our quest will go on within the wisdom that God alone, the Creator of all, may give.

We propose that a return to absolutes would be to the pleasure of the Creator, since relative thinking distorts our view of the universe. The Psalmist says, in Psalm 19, that the heavens declare the glory of God. Such glory is seen through the things that the eye can see, and this must not be distorted by science founded on errors.

We recall that it is the two-way 'average' passage of light that we can measure. One-way passage of light is open to fresh prayerful questioning. If the ether exists, we do not know how it was stretched out or how it continues to expand. We do not know if the local speed of light anywhere in the universe varies or has varied as the created universe settled. We may never know. We could speculate on local light speeds elsewhere in the universe, quite different from the 186,000 miles per second that is measured in our local environment; perhaps up to much higher speeds in other local areas or in times past. We may speculate on this and many other things and are free to do so.[10] But in the end, it is faith in our Creator that pleases Him and knowledge within the bounds of revelation that He sets.

May our prayerful quest go on with all integrity and honour to the One who made all that is.

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2. See, for example, Rindler, W., *Essential Relativity*, 2nd edn, Springer Verlag, New York, pp. 31–33, 1986.
3. A useful book that contains five papers written in 1905, two of which were the beginnings of Relativity Theory, is *Einstein's Miraculous Year,* edited and introduced by John Stachel, Princeton University Press, 1998. The two postulates of Relativity are on p. 124.
4. These quotations are exactly as written by Einstein except that we have written the velocity of light as 'c' not 'V'.
5. Einstein, A., Ether and the theory of relativity; in: *Sidelights on Relativity*, Dover Publications, New York, pp. 3–24, 2010. See also Humphreys, D.R., *Starlight and Time,* Master Books, Green Forest AR, p. 84, 1994.
6. This idea has been proposed by others, e.g. in D. Russell Humphreys, *op. cit.* p. 84, we read: "The speed of light would be constant with respect to such an ether, and then the equations of relativity would require that clocks and measuring rods moving with respect to the ether change in such a way as to give the same number for the speed of light every time, i.e. objects moving through the ether would be changed by that motion. Clocks would actually slow down, measuring rods would actually shorten, and the speed of light would seem to be independent of motion [Rindler, ref. 2, p. 7]. By re-affirming an absolute reference frame, this view of relativity dumps the philosophical baggage and resolves the paradoxes."
7. This is quite different from SR. If two cars approach one another at speeds u and v, the speed each is approaching the other is u + v. If the second moves away from the first, the first closes on it at the speed u – v. In our fixed frame of reference, light is travelling in the ether at speed c. If the apparatus (light source and reflector) is moving in the ether, we add or subtract their speed of movement as applicable to find the relative speed of the instruments to the light that travels in the ether.
8. Pym, F. and Denton, C., *Einstein's Predicament,* Two-edged Sword Publications, pp. 37–49, 2005. An introduction to the theory is also available on Absolute Space and Time | youtube.
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10. For example, we might speculate that when a new star appeared on Day 4 of Creation Week around 6,000 years ago, the universe would be in the early stages of expansion. The light burst forth from the star and then continued its journey of thousands of years to the earth through a changing universe that continued to expand. A simple order of magnitude calculation can show that light leaving the star might have travelled initially at 1,000 times the speed of light that we measure today.

Clifford Denton *studied mathematics at the University of Cambridge after a career as an RAF pilot. He then taught mathematics and computer studies before engaging in government funded research projects at the University of Oxford, relating to gifted children, and was also awarded a D. Phil. Following this has been 40 years of full time Christian ministry including the establishment and support of Bible schools around the world. Currently, he and his wife are establishing a school in the UK for strengthening families who are teaching their children at home. A building at the school is set aside to focus on the God of Creation.*

What's wrong with being wrong: part 5—a more than cursory look into evolutionary ethics

Marc Kay

Previous parts critiqued three major evolutionary explanations for morality's appearance: group selection, kin selection, and reciprocal altruism. These fall short of coming to grips with morality's quintessential non-materiality. In order to sidestep this difficulty, materialists argued for an ill-defined 'proto-morality' arising in non-human animals and redefined morality as survival value. Survival is serially cashed out in terms of the number of an organism's offspring and is a measure of how successfully an individual's 'altruistic' genes are passed on.
In addition to these neo-Darwinian explanations for morality's appearance, there are multiple auxiliary explanations. This part focuses on E.O. Wilson's sociobiology. It, too, lacks sufficient epistemological and empirical warrant to explain morality.

"Greed is good. Greed is right. Greed works. Greed clarifies, cuts through, and captures the essence of the evolutionary spirit" (Michael Douglas's character, Gordon Gekko, in Oliver Stone's 1987 film *Wall Street*).

Sociobiology

"Sociobiology", wrote E.O. Wilson (figure 1), "is the systematic study of the biological basis of all social behaviour."[1] The significance of human sociobiology is that

> "… science is now in a position to approach ... the very origin and meaning of human values, from which all ethical pronouncements and much of political practice flow. … to the extent that the biological interpretation noted here proves correct, men have rights that are innate, rooted in the ineradicable drives for survival and self-esteem."[2]

Wilson, a myrmecologist by training (he was called the 'ant man'), claimed that his and others' studies of animals brought a clearer, more accurate understanding of the evolution of human society and its values. Although human societies are exceedingly more complex than the animal world, he believed both had evolved through not too dissimilar processes of cooperation and the like. Noteworthy for its lack of historical details, sociobiology couples these primeval, communal life-forms with the rise of *Homo sapiens*. That criticism aside, sociobiology is important. As two editors noted:

> "[it] is not *merely* an abstract, academic speciality, nor *merely* a piece of traditional sexual or political theory designed to put minorities in their place, but a purportedly scientific theory which carries with it a controversial world view with implications for a wide variety of political and economic policies with respect to race, sex, hierarchy, institutions, and control."[3]

We began as insects?

Lower order animals, such as ants (figure 2) and bees, are social. Their colonies are vast and are rigidly controlled by genetics, with all members contributing to the greater good of maximizing survival. Fast forward to the Pliocene, droughts changed the forests to savannahs and proto-man was forced to adapt to this new ecological niche. Through further mutation and natural selection, these human-like creatures acquired the ability to partially transcend the deterministic force of its genes and create culture:

> "Human beings adapt to environment in terms of a socially transmitted system of behaviour and meanings called 'culture'. The neurological capacity for this system apparently evolved in response to a rapidly changing ecology in which maximum behavioural flexibility won out over more stable ('wired in') behavioural mechanisms ... . It has the unique and emergent property of itself evolving."[4]

The argument is simple: human ancestors having a capacity for culture survived better than those who didn't and would reproduce more prolifically. There would be a feedback effect, and greater cultural invention would dominate and outstrip biological evolution. Feedback loops are a standard mechanism invoked to tie biology to morality and culture and lend theoretical support to impotent evolutionary explanations. The Ukrainian geneticist Theodosius Dobzhansky recognized feedback's apologetic value in evolutionary discussions:

> "What is more, since the environment in which man lives is in the first place his sociocultural environment, the genetic changes induced by culture must affect

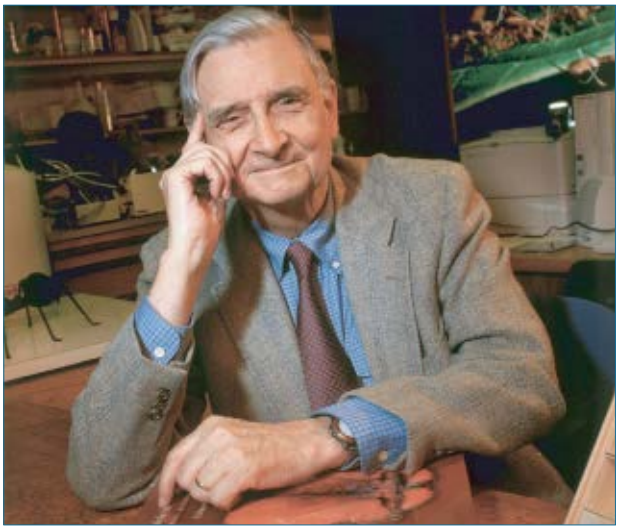

Figure 1. E.O. Wilson's *Sociobiology: a New Synthesis* has been a seminal work, for proponents and critics alike.

> man's fitness for culture and hence may affect culture. The process thus becomes self-sustaining. Biological changes increase the fitness for, and the dependence of their carriers on culture, and therefore stimulate cultural developments; cultural developments in turn instigate further genetic changes. This amounts to a positive feedback relationship between the cultural and the biological evolutions. The positive feedback explains the great evolutionary change, so great that it creates the illusion of an unbridgeable gap between our animal ancestors and ourselves … . Waddington [ref. cited] has shown clearly that our biological evolution has instilled in us no ethics and no ability to discriminate between good and evil. What the evolution has done is to make us 'ethicizing beings', and 'authority acceptors' particularly in childhood. But what ethical principles or goals we accept as taught by others, or devise for ourselves, comes not from our genes but from our superorganic inheritance, from our culture."[5]

Wilson seems intent on straddling two irreconcilable camps: the contest is between hardcore culture environmentalists, chiefly the Left, and genetic determinists (of which Wilson stands accused of being a card-carrying member by the former). His ostensibly conciliatory middle ground is not a helpful response. No-one denies the impact of culture; the problem surfaces only when fulfilling the epistemic burden of how biology and culture are related. Even more demanding is the weightier challenge of how morality and ethics, the concepts of 'good', 'wrong', 'evil', became merely the spur for individuals or groups to out-evolve their competitors. Morality is neither a glass half empty nor one half full; it's either there or it isn't. These very details, side-stepped by Wilson (and Dobzhansky), define morality.

The other conundrum for the evolutionist is how genetic determinism overcame genetic determinism to produce genetic information that allowed a creature to overcome its genetically fixed behaviour that one cannot overcome its genetically fixed programming.[6] Feedback, elegantly and technically persuasive, nevertheless is nothing more than a secular *deus ex machina* given a free pass in order to save the idea.

The backlash against Wilson

The publication of Wilson's *Sociobiology* generated as much controversy as it did praise. It split the evolutionary academic world and unleashed a firestorm of invective-filled accusations splashed through the letters-to-the-editors pages of journals and broadsheet newspapers.

Sociobiology has strong support.[7] Peter Singer, in keeping with his philosophically God-drained universe, believes the discipline deserves our attention because "once we abandon Divine Creation and accept that homo sapiens is one among several species of social mammals, the key tenet of sociobiology must be taken seriously."[8]

As for detractors, a lengthy list of Harvard[9] staff co-signed a letter accusing Wilson of using "a number of strategies and sleights of hand which dispel any claim for logical or factual continuity", "biological determinism" and "[using] a speculative reconstruction [sic] of human prehistory".[10] A Leftist coterie, including Stephen Jay Gould and Richard Lewontin, took aim, grouping Wilson with Herbert Spencer and the Nazi scientist Konrad Lorenz. His accusers claimed "his favorite analogies arise by a twisted process", and that sociobiological theory is unfalsifiable and can only be supported by making up 'just-so' stories.[11]

Empathy for the Left's scorn is understandable. Wilson occasionally punctuated his animal studies with observations pulled from bizarrely incorrigible and immoral human societies. He draws upon field studies which have noted, for example, the !Kung society has a stratum of people "who never try to make it, live in run-down huts, and show little pride in themselves or their work." He mentions the Ik of Uganda, briefly describing their less-than-animal community structure: children are abandoned at age three, food is the only value and death is amusing because it means more food for survivors.[12]

Such language is, for the Left, invitation for a fight. They accused Wilson of genetic determinism and of upholding the sociopolitical status quo. Wilson did not wait long to return fire against these charges, stridently defending himself in the process. He accused his attackers of 'vigilantism', "judg[ing]

a work of science according to whether it conforms to the political convictions of the judges" and misrepresenting his arguments.[13]

After a close reread of Wilson's arguments, it remains unclear as to how much of a non-determinist Wilson really is. This especially stands out when he confusingly writes:

> "Although the genes have given away most of their sovereignty, they maintain a certain amount of influence in at least the behavioural qualities that underlie variations between cultures … . Even a small portion of this variance invested in population differences might predispose societies toward cultural differences … . It is not valid to point to the absence of a behavioural trait in one or a few societies as conclusive evidence that the trait is environmentally induced and has no genetic disposition in man. The very opposite could be true."[14]

The moral rights that Wilson believes are "innate [and] rooted in the ineradicable drives for survival and self-esteem" remain an ambiguity in Wilson's apologetic. He argues that human values are, by virtue of our biological history, subsumed by our evolutionary requirement to survive. This strikes me as a little baffling. Is he claiming that our survival is, ultimately, the only thing that counts? Does he mean that what brought us to this present point are those qualities which aided our resilience to extinction? If so, this signals a crude Social Darwinism. Wilson hints at such—one reason for the vituperative outbursts against him— when he declares, "For if the whole process of our life is directed toward preserving our species and personal genes, preparing for future generations is an expression of the highest morality of which human beings are capable."[15] After all, in a moment of cold reductionism he expresses his belief that "in evolutionary time the individual organism counts for almost nothing [and a person] is only DNA's way of making more DNA."[16]

Wilson doesn't exactly spell out what form this 'highest morality' might conceivably take; nevertheless, linking it merely to the continued existence of humans, at the expense of the weak, as evolution demands, is clearly antithetical to a Christian ethic.[17] If it be granted that Wilson's is not some recrudescence, unintentional or otherwise, of Social Darwinism, the challenge is to discover what his 'highest' morality is grounded upon.

Sociobiology's meta-ethics[18]

Wilson collaborated with philosopher Michael Ruse to crudely dismiss moral objective realism. In its place arrived a poorly conceived, fallacy-ridden scientism. Utterly seduced by materialism, they failed to notice their enterprise was nothing more than an atavistic rehash of logical positivism, a philosophy long ago refuted on its own fundamental

Image: Mehmet Karatay, Wikimedia / CC BY-SA 3.0

Figure 2. Wilson argues that morality's source can be 'historically' traced from ant colonies and other 'altruistic' insect life.

epistemological criterion.[19] Their belief was that "implicit in the scientific interpretation of moral behaviour is a conclusion of central importance to philosophy, namely that there can be no genuinely objective external ethical premises. Everything that we know about the evolutionary process indicates that no such extrasomatic guides exist."[20]

Although the second proposition ostensibly presents as one developed from a lengthy and exhaustive investigation of nature, it would appear that the initial premise is not much more than a clever, but disingenuous, refashioning of positivism's most important axiom, a rejection of metaphysics.[21] Of course, this rejection itself assumes the unmistakable form of a metaphysical proposition. Positivists boasted of the death of metaphysics by *metaphysically* limiting knowledge to the empirically verifiable or tautologies. Not only does it shoot itself in the foot by this claim, it also question-begs the truth of its antimetaphysics proposition.[22] Indeed, as Putnam underscored, "The difficulty, which is faced by all versions of positivism, is that positivist exclusion principles are always self-referentially inconsistent. In short, positivism produced a conception of rationality so narrow as to exclude the very activity of producing that conception."[23]

How might such an epistemology be justified? One attempt comes from among their own ranks. Stephen Jay Gould pointed out what he thought was a category error. Science and religion, he complained, had no genuine communication between each other, labelling this the concept of non-overlapping magisteria (NOMA).[24]

However, a well-informed Christian can do far better. Sociobiology's striking vulnerability lies neither in its infinitely adjustable just-so stories nor in its alleged scientific

appeal to nature's experiments, what biologists would term field studies. Where Wilson and the others are most exposed is in their project to account for what it means to be moral. Cracks begin to appear once sociobiology's attempts to set out a meta-ethic are examined.

Wilson sanctions a non-cognitivist meta-ethic.[25] Wilson (like David Hume), believes ethics is sourced in emotions, which are ultimately biological. As a consequence, Wilson argues the ethical debate be removed from philosophers and biologicized, looking for clues within the non-human order of nature:

> "The biologist, who is concerned with questions of physiology and evolutionary history, realizes that self-knowledge is constrained and shaped by the emotional control centers in the hypothalamus and limbic system of the brain. These centers flood our consciousness with all the emotions—hate, love, guilt, fear, and others—that are consulted by ethical philosophers who wish to intuit the standards of good and evil. What, we are then compelled to ask, made the hypothalamus and limbic system? They evolved by natural selection. That simple biological statement must be pursued to explain ethics and ethical philosophers, if not epistemology and epistemologists, at all depths."[26]

He, with Ruse, elaborates: "human beings function better if they are deceived by their genes into thinking that there is a disinterested objective morality binding upon them, which all should obey."[27] In other words, Wilson, like Ruse, holds that our best genetic interests are to be aligned with the *belief* that morality is objective, despite not being so. What's more, a looming relativism finds its footing: "ethical laws can be changed, at the deepest level, by genetic evolution. This is obviously quite inconsistent with the notion of morality as a set of objective, eternal verities. Morality is rooted in contingent human nature, through and through."[28] Notwithstanding this sanguine expectation, Wilson's rejection of genuine objectivity comes with an awful price tag. Roll those genetic dice and what results is Isaiah's foresight of "those who call evil good, and good evil; who put darkness for light, and light for darkness; who put bitter for sweet, and sweet for bitter!"

Ruse and Wilson are not blind; they really do comprehend the logical, unpalatable fall-out from a meta-ethic which rejects ethical absoluteness: "A common argument raised against the materialist view of human nature is that if ethical premises are not objective and external to mankind, the individual is free to pick his own code of conduct regardless of the effect on others."[29]

Having so economically unpacked their opponents' rejoinder, one would expect their comeback to actually engage with it. Unfortunately, what is served up is a mangled question-begging reworking of some quite uninspired get-out-of-jail excuses:

- evolution is confirmed as fact and so moral objectivism is false
- appearances to the contrary and not withstanding all their differences (read, specialpleading), human moralities really converge (read, when cultures are at complete odds with each other, they aren't), and
- saving the evasively best and most morally drained to last, "the materialist view of the origin of morality is probably less threatening to moral practice than a religious or otherwise non-materialist view, for when moral beliefs are studied empirically, they are less likely to deceive."[30]

> "Be wary of the probable: start by believing the incredible" (Émile Gaboriau, *Monsieur Lecoq*, 1869, ch. 8).

The critics respond

Critics were quick with rejoinders, unfortunately replacing some rather muddled reasoning with even more obtuse reasoning.

In his book-length attack, Philip Kitcher, although himself an evolutionist, called sociobiology's extension of animal studies to human behaviour a 'new philosophers' stone', relabelling it 'pop' sociobiology because it "advance[s] grand claims about human nature and human social institutions."[31] Kitcher doubted sociobiology could demonstrate that an animal group's behaviour would maximize its fitness. Despite not applying his methodological fault-finding to evolution, Kitcher nevertheless noted the dearth of rigorously critical analysis in the sociobiology project. His lengthy list of doubts and flaws includes:

- whether the base assumptions relying on prior knowledge of the behaviour were precisely formulated
- if all animals in a group were behaving similarly
- if there was question-begging ("if evolutionary assumptions are being smuggled in via descriptions of behaviour that identify a function for it")
- the use of vague or ambiguous language
- how tight a fit with the actual observations the models employed were, and
- whether a more promising analysis better captured the history of selection.[32]

Kitcher challenged Wilson as to whether his explanation of the supposed history of how humans acquired ethical thinking necessarily eliminated any claims to moral objectivity. He wrote:

> "Nor should we believe that to reconstruct the history of ethics, say by showing how ethical

> principles originated in myths used to buttress social arrangements (for example, the myth of a deity who would punish those who violated the precepts), is to cast doubt on the objectivity or the correctness of the principles we espouse … . Wilson is far too hasty in assuming that the evolutionary scenario he gives for the emergence of religious ideas—a scenario that stresses the adaptive advantages of religious beliefs and practices—undercuts the doctrine that religious statements are true."[33]

Kitcher insightfully pointed out that Wilson's subjectivist meta-ethic must introduce entirely disparate moral standards for different communities. Within a Wilsonian emotivism meta-ethic, an epistemic formulated to disinterestedly differentiate between the morally perverse and a bad oyster is illusory:

> "Ethical statements turn out to be on par with statements we make when moved by our gastronomic preferences. Just as there is no objective standard against which those who like lutefish are to be judged, so too there is no objective appraisal of those who disagree with us about the propriety of killing innocent children. Their hypothalamic-limbic complexes incline them to different emotional responses. That is all."[34]

Notwithstanding his unease at the implications of a Wilsonian moral epistemology, Kitcher nonetheless acknowledged the real existence of widely discordant ethical principles, but attempted to minimize this uncomfortable truth. In a confused defence for his rejection of Wilsonian ethics, and clearly wishing to erect a robust epistemic barricade against the egregiously wicked, Kitcher nevertheless failed. Misleading in his presumptive depiction of the moral arena as 'objective', his rejection falls apart at the first hurdle:

> "There are numerous areas of human inquiry in which theoretical disputes persist unresolved, and in which we do not abandon the idea that there is an ultimate possibility of objective solution. Just as the fact that there have been … large theoretical disputes in evolutionary biology does not tell against the existence of a consensus on all kinds of important claims about the history of life, so too the presence of rival philosophical theories of the foundations of ethics should not blind us to the substantial areas in which reflective people agree in their moral appraisals."[35]

What initially appears as rejection of a subjectivist-styled ethics, Kitcher opened his own Pandora's box by suggesting "moral goodness [could be] equated with the maximization of human happiness."[36] This is a version of utilitarianism, and, stripped of all the prolific discussion concerning its merits, failings, and the inestimable pain-and-pleasure calculi, when applied society-wide, it remains essentially a winner-take-all normative theory. Any sociopolitical system basing itself on maximizing people's happiness or welfare can only tally opposing and supporting factors, which is just another way of saying the majority popular opinion wins. To put it even more starkly, each individual's assessment of his own pain or pleasure is *subjective*, and a tally of these doesn't magically sum to something *objective*; it is just an even bigger collection of people's personal likes and dislikes.[37]

When it comes to satisfying the ethical objectivist skeptic's query as to what form the unchanging moral realm takes, Kitcher tacitly admits ignorance, replacing a cogent defence with an (inapposite) analogy. He gestures towards mathematics, reminding us this discipline can be regarded as objective because it can be carried out quite successfully without agreement concerning the reality of an objective realm of abstract entities, such as numbers and sets. Rational people can surrender a belief that mathematical statements are objectively true or false without harming their belief concerning the objectivity of mathematics. Similar responses can be levelled against moral scepticism:

> "[We can possibly] give up the idea of objective truth or falsehood for ethical statements in favour of the notion that some statements are objectively *justified* while others are not. Thus we may try to work out the view that, strictly speaking, 'Killing innocent children is morally wrong' is neither true or false."[38]

While here is not the place to take sides concerning the merits or flaws of the objectivity of mathematics dispute,[39] it would seem Kitcher commits the Fallacy of the False Analogy.[40] Mathematics enables bridges to be built, facilitates cancer cures and sends probes beyond our solar system. Whether mathematics is objective and relies on an actual Pythagorean or Platonic World of numbers or is eternally true because it's sourced within the Triune God is irrelevant because no-one would rationally disagree with mathematics' instrumental value. On the other hand, rejecting the absoluteness of ethical statements, particularly in more emotionally laden areas, while opting for mere instrumental justification, is not only meaningless, but outright parlous. It is relativism by stealth.

How to justify that it is wrong to kill innocent children, if going on current evolutionists' (failed) projects to do so, serially begs the question that it is. The absence of any external irreducible, unchanging, human-independent standard is the crux of the issue. And in confronting the evolutionist on this issue, given the materialist metaphysic of evolution, there remains the thorn of how to impart sense to the notion of moral objectivity. Kitcher's backing for a flaccid moral objectivism is curious, not because it succeeds where other materialists have failed to enlighten us, but because he says so little in actual support.

Image: David Shankbone, Wikimedia / CC BY 3.0

Figure 3. Dawkins, like Wilson, holds to a materialist worldview according to which God is an epistemological superfluity and morality is merely a means to an instrumental genetic end.

The best Kitcher offers is a partial tweaking of John Rawls' much cited and influential 'impartial perspective' theory or 'original position' as set out in his *A Theory of Justice*.[41] Rawls argued that if people were hypothetically placed on a level playing field, what he terms a 'veil of ignorance', blind to their own interests and actual privileged position of being, say, rich or powerful, then on the basis of *rationality* alone, all participants would seek equal justice for all.[42]

Having used what he found worthwhile in Rawls, Kitcher then discards him and returns to his evolutionary base, declaring:

> "To the extent that people can be viewed as maximizing their own inclusive fitness through cooperation with others, apparent conflicts of interest may be diagnosed as situations in which all the parties maximize their inclusive fitness by coordinating their behaviour."[43]

And what about the workplace psychopath or the everyday, run-of-the-mill, dishonest person? Some of these miscreants may just still secretly cherish a winner-take-all approach to ending conflict, and no amount of rational argument on the basis of cooperation can dissuade them from the belief that cooperation leaves you with less rather than more.

Despite his open repudiation of any traditional religious solution to moral objectivity, Kitcher nevertheless maintains moral objectivity can be sustained, ending his book with an equally, though unexamined, religious metaphysic: "Sociobiology has nothing to offer. There is no higher standpoint than [biology and no] impartial perspective."[44] Of course, biology is just his scientific guise for naturalism, nothing more, nothing less.

In the end, Wilson and Kitcher are really saying the same thing. In all of his nit-picking of Wilson, it's easy to overlook the fact that Kitcher's own 'historical' account does not seem to wander too far from Wilson's. What applies to Wilson can apply with equal vigour to Kitcher. His own just-so explanation reads as follows:

> "Somewhere in hominid evolution came a step that provided us with a psychological device for overcoming wantonness. I am inclined to think of it as part of what made us fully human. Perhaps it began with an awareness that certain forms of projected behaviour might have troublesome results … . I suspect that it was linked to the evolution of our linguistic ability. As I envisage it … [a]t this stage, I conjecture, there began a process of cultural evolution. Different small bands of human beings tried out various sets of normative resources—rules, stories, myths, images … perhaps they offered greater reproductive success … increased cooperation … . Most of this process is invisible … perhaps … or perhaps … . Whichever alternative one selects, these phenomena reveal an increased capacity for cooperation and social interaction … . Whether or not we can ever do more than guess."[45]

And so on.[46] It comes down to this: One just-so story is preferred over a competitor's.

Even when attempting clarification in response to the barrage of received criticism, Wilson remained ambiguous. Just how much moral behaviour is underwritten by genes and how much can be measured by the force of culture remains a mystery. Regardless of the answer—assuming there is one—morality, within a materialist worldview, requires being jump-started by genes, or, at least, something acting as their proxy (figure 3). Whatever is claimed can't be merely descriptive; it has to actually be seen to perform work. That is, the solution must be functional.[47]

Flanagan makes the astute argument that despite Wilson's dependence on inclusive fitness, reciprocal altruism and selfish genes to explain morality's origin, they are "vacuous and diversionary" because these are "unhelpful … in trying to explain [an individual's] actual moral sense". Illustrating this point, Flanagan contrasts and compares two individuals,

Wittgenstein and the Ayatollah Khomeini. His initial criticism is that inclusive genetic fitness is a universal, and so the only apposite factors influencing differing moralities, facts about individuals' cultures and their life stories lie outside of sociobiology's field of influence: "it is all the other facts, the only things which vary, which do the explaining, not inclusive genetic fitness [because it is] perfectly controlled and universal from the start."[48]

Burian upbraids Wilson for "tell[ing] a logically satisfactory story to account for any behaviour one chooses [b]ut the untestability and arbitrariness of the components prevents it from being of genuine explanatory interest." Without any recognition of its irony, Burian further criticises sociobiology's adherents for not testing alternative tales and thus failing to realize "that a better story may yet be invented which can eliminate the current survivor." Burian suggests Wilson deliberately chose only the stories which did not conflict with the sociobiological framework, "and then maintain[ed] that the evidence is consistent with the proposed hypothesis."[49] In other words, Burian implies that it was rigged from the outset, Wilson having question-begged the truth of his explanation.

Where to from here?

Far more concerning—underscored, ironically, by his Marxist-inspired academic detractors—is that Wilson's sociobiological aspirations seem to be lifted from the script of a Huxleyan world. He appears sold on a vision that our genes will be eventually manipulated to achieve a form of Nietzschean moral Übermensch:

> "The transition from purely phenomenological to fundamental theory in sociology must await a full, neuronal explanation of the human brain. Only when the machinery can be torn down on paper at the level of the cell and put together again will the properties of emotion and ethical judgment come clear. Simulations can then be employed to estimate the full range of behavioral responses and the precision of their homeostatic controls … . Cognition will be translated into circuitry. Learning and creativeness will be defined as the alteration of specific portions of the cognitive machinery regulated by input from the emotive centers. Having cannibalized psychology, the new neurobiology will yield an enduring set of first principles for sociology. The role of evolutionary sociobiology ... will attempt to reconstruct the history of the machinery [of the brain] and to identify the adaptive significance of each of its functions. Some of the functions are almost certainly obsolete … . Others may prove currently adaptive at the level of the individual and family but maladaptive at the level of the group—or the reverse. If the decision is taken to mould cultures to fit the requirements of the ecological steady state, some behaviours can be altered experientially without emotional damage or loss in creativity. Others cannot. Uncertainty in this matter means that Skinner's dream of a culture pre-designed for happiness will surely have to wait for the new neurobiology. A genetically accurate and hence completely fair code of ethics must also wait."[50]

If that fails to communicate Wilson's future dystopian vision, the following surely clears away any misunderstanding:

> "'Soft-core' altruism ... is ultimately selfish. The 'altruist' expects reciprocation from society for himself or his closest relatives. His good behaviour is calculating, often in a wholly conscious way, and his manoeuvres are orchestrated by the excruciatingly intricate sanctions and demands of society. The capacity for soft-core altruism can be expected to have evolved primarily by selection of individuals and to be deeply influenced by the vagaries of cultural evolution. Its psychological vehicles are lying, pretence, and deceit, including self-deceit, because the actor is most convincing who believes that his performance is real ... . Human beings appear to be sufficiently selfish and calculating to be capable of indefinitely greater harmony and social homeostasis ... . True selfishness, if obedient to the other constraints of mammalian biology, is the key to a more nearly perfect social contract."[51]

"Nothing is so easy as to deceive oneself; for what we wish, we readily believe" (Demosthenes 384–322 BC).

Conclusion

Wilson's sociobiological thesis is consistent with the materialist worldview that humans are nothing but evolved animals. Morality must, somehow, have its source in a non-human genealogy. With Wilson its origin begins in the insect world.

Parallel with this belief is his rejection of an objective, cognitivist meta-ethic. In harmony with Ruse, Wilson pushes the indemonstrable: genes have tricked 'us' to believe we possess an objective morality when in fact no such creature exists. Worse still, his repudiation of genetic determinism notwithstanding, Wilson's ultimate reliance on remaking neurobiological man in the image of a God-expelled secular humanism heralds an atavistic restoking of the 20th century's

political and social experiments, which marked it out as the most bloodied century the world has witnessed.[52]

Some final thoughts. Wilson, due to his belief that evolution never ceases because the underlying genetics which programs and fosters morality is fluid, is forced to face up to the difficulties that this brings to the surface. In a very limited, final few pages he concludes that a form of moral pluralism—what else could he do?— is the only justified socio-political alternative. However, one suspects that this conclusion, while fuelled by his evolutionary bias, is not entirely the product of it. Lurking behind this coda there seems to be a rejection of anything resembling a Judeo-Christian ethic:

> "If there is any truth to this theory of innate moral pluralism, the requirement for an evolutionary approach to ethics is self-evident. It should also be clear that no single set of moral standards can be applied to all human populations, let alone all sex-age classes within each population. To impose a uniform code is therefore to create complex, intractable moral dilemmas—these, of course, are the current condition of mankind."[53]

Wilson doesn't elaborate on this intractability—he merely expects the reader to take his word for it. 'Pluralism' is newspeak for cultural and moral relativism, no matter how 'successfully' ethics is 'biologicized'; and it suffers just as much from the usual, and quite logical, criticisms any form of ethical relativism attracts. Just how convincing Wilson's censure of, say, pedophilia would be, given his dismissal of actual and transcendent ethical absolutes, is not too hard to gauge.

When accounting for a behaviour, phenotype or moral faculty, sociobiologists have a tendency to reify their well-spun Kiplingesque tale (something common to all evolutionary explanations!). What begins as a protatic 'possible' or a cautious 'imagine' terminates in the apodictic. Although trumpeted with a confabulatory confidence that their construction entails the same evidentiary stature as the events at Runnymede or Pearl Harbour, the air-drawn nevertheless demands a body. Fischer labelled this the Fallacy of the Hypostatized Proof: "this form of error commonly occurs when a historian reifies a historiographical interpretation and substitutes it for the actual historical event it allegedly represents."[54]

How is this at all possible? One sociobiologist apologist provides a justification:

> "Numerous philosophers of history have claimed that there are a number of additional criteria that distinguish stories and myths from history. For example, there is near unanimity of opinion about the claim that among the properties possessed by history, as opposed to stories and myths, are internal consistency, the avowed intention to produce a 'factual' account of past events, and the willingness of historians to test their accounts against publicly available forms of evidence. Stories normally lack all of these characteristics. If such criteria can be utilized to distinguish history from stories, myths, and fables, then surely sociobiological accounts count as history, not stories. Sociobiological explanations of the incest taboo, homosexuality, panhandling among humans, and inheritance patterns among persons in various cultural settings are constructed so as to be grounded in an established theory … to be 'factual', and to be testable by publicly available evidence … . But the real point at issue is that many sociobiological accounts do approximate the classificatory standards for being understood as history (perhaps false history but still history) operative in the social sciences and human history, which is probably all that can reasonably be asked of sociobiological hypotheses on methodological grounds at this point in time. While sociobiological accounts of the origins of social behavior may indeed be slap-dash or false, they are patently not fictions or fables."[55]

So, the evolutionary history of, say, altruism, or the rise of morality more generally, need not be true or accurate; and if they are neither, the explanation is not necessarily a work of fiction. Go figure!

In the next part I will review a number of other attempts to explain morality's origin according to evolutionary dogma.

References

1. Wilson, E.O., *Sociobiology: The New Synthesis*, The Belknap Press of Harvard University Press, Cambridge, MS, p. 22, 2000. Arguably the first appearance of a connection between sociology and biology was in 1967 with the publication of Bruce Eckland's article, unimaginatively titled Genetics and sociology: a reconsideration, *American Sociological Review* **32**(2):173–194, 1967. Wilson's initial exposure to the general public was enormous. He gave interviews to *The New York Times Magazine*, *House and Garden*, *People*, as well as having articles written about sociobiology, *inter alia*, in *Time*, *Newsweek*, *Playboy* (the article's title was, predictably, "New science tells us why men cheat on their wives"), *Mother Jones*, *Omni*, and *Boston*. For reference details see the introductory editors' note to the special double issue of Leeds, A. and Dusek, V. (Eds.), *The Philosophical Forum* **XIII**(2–3):iv–xv, Winter-Spring 1981–1982. Like most evolutionary explanations for morality's rise, sociobiology has suffered the same fate of becoming an historic relic. Notwithstanding this, it would be wrong to say that Wilson's original ideas have lost all influence. After all, man and all other life are connected through a common biological history. I thank an anonymous reviewer for raising this point.
2. Wilson, E.O., Dialogue. The response: academic vigilantism and the political significance of sociobiology, *BioScience* **26**(3):183, 187–190, Mar 1976; p. 189. It should be pointed out that any other explanation, apart from the material, is not given a second look. Nothing could be made clearer than Lionel Tiger and Robin Fox's boast that "We have confidently asserted that identifiable propensities for [human] behaviour are in the wiring. Unless we look to divine intervention, these got there by the same route as they got into the wiring of any other animal: by mutation and natural selection." Tiger, L. and Fox, R., The human biogram; in: Caplan, A.L (Ed.), *The Sociobiology Debate: Readings on the ethical and scientific issues concerning sociobiology*, Harper and Row, NY, p. 57, 1978. The authors are referred to in a positive light by Wilson in his *Sociobiology*, ref. 2, pp. 547–550.

3. Leeds and Dusek, ref. 1, pp. viii–ix.
4. Barkow, J.H., Culture and sociobiology, *American Anthropologist* **80**(1):5–20, Mar 1978; p. 9. The enormous plasticity of evolutionary explanation on this speculative wiring history can be witnessed in the juxtaposition of two mutually exclusive views. Writing in 1971, Tiger and Fox claimed that "The theory used to be that, for some reason or other, at some time or other, the human brain expanded to the point where it was capable of producing first symbols and then culture. This no longer seems plausible. [In reality i]t was *after* they started doing cultural things that the brain grew in size and complexity." Tiger, L., and Fox, R., ref. 2, pp. 58–59.
5. Dobzhansky, T., Anthropology and the natural sciences—the problem of human evolution, *Current Anthropology* **4**(2):138, 146–148, Apr 1963; p. 147.
6. On top of all that, the possibility has also been suggested that cultural evolution, once emancipated from biology, reduces the fitness of the group. Durham, in passing, points to this possibility: "Although the resulting process of cultural selection would normally result in adaptive phenotypic attributes, I should point out that it actually easier to conceive of cultural influences getting 'off track' in the evolution of a phenotype than it is for biological influences. Maladaptive cultural practices *can* [emphasis in original] be maintained at substantial frequency in a population, particularly when [human biases or forces that keep culture on track of the adaptive optima] are overridden or prevented from functioning. … Maladaptive behaviors can also recur through the conscious or deliberate choice of individuals to behave counter to their reproductive interests." (Durham, W.H., Toward a coevolutionary theory of human biology and culture: in: Caplan ref. 2, p. 435.) Further, on the premise that not all behaviour is genetically determined, it is worth considering the havoc a selfish individual or individuals (cheats) may impose on group fitness. I would think many of the communities cited and described in Robert Edgerton's *Sick Societies: Challenging the myth of primitive harmony*, The Free Press, NY, 1992, would support this criticism.
7. To what degree it is true now is difficult to assess but, soon after the time of its publication, Wilson's ideas were taken up by the European Far Right, despite Wilson's profession of "a fairly orthodox academic liberal political stance". Leeds and Dusek, ref. 1, pp. ix ff. These editors point out that although sociobiology in the US "is academically part of the liberal mainstream", some American neo-conservatives have used Wilson's theory to justify a range of their beliefs. Sociobiology's ecumenical net is no better illustrated than "Guy Hocquenghem. Hocquenghem was a gay activist who wrote for the French 'Maoist' journal, *Liberation*, at the same time the New Right surfaced, and who, oddly, was sympathetic to its biologism and even some of its racism." Leeds and Dusek, ref. 1, p. xi.
8. Singer, P., Ethics and sociobiology, *Philosophy and Public Affairs* **11**(1):42, Winter 1982. It should be noted that Singer's praise, however, is accompanied by some criticism.
9. Up to 1996 Harvard was the university to which Wilson was tenured.
10. Allen, E., Beckwith, B., Beckwith, J., Chorover, S. *et al.*, Against 'sociobiology', *The New York Review of Books*, pp. 182, 184–186, 13 Nov 1975.
11. Dialogue (The Critique), Sociobiology—another biological determinism, *BioScience* **26**(3):182,184–186, Mar 1976. All of these accusations would, of course, strike any creationist as quite rich given they comprise the same methodological and philosophical faults creationists time and time again level against evolutionary theory generally and its just-so stories specifically. As noted by Leeds and Dusek, "An interesting sidelight on this dispute is that some critics of the unfalsifiability of sociobiology have been led by their own criticism to examine more carefully those parts of evolutionary theory which are, to some extent, guilty of the faults which they first noted most glaringly in sociobiology, especially concerning the concept of adaptation and adaptational stories" (ref. 1, pp. xvii–xviii). Leeds and Dusek have a useful summary of the main academic criticisms on pp. xi–xii, and following this the negative reception in the popular media and political sphere.

    Pushed into a corner, sociobiology quickly defaults to a theory-saving plasticity. In an article aimed to rescue Wilson's ideas from his detractors, Barkow recounts a conversation he had with the evolutionary psychologist, Daniel Freedman. Addressing the counterfactual that falling birth rates in Western countries seem to undermine Wilson's theory that we seek to maximize our inclusive fitness, the salient anomaly is matter-of-factly brushed aside. Barkow boasts that "Even if we are [working against our fitness], such a situation would in no way put sociobiology in question [because] sociobiology is indeed sufficiently flexible to be applied to human behavior without automatic contradiction." Flexing this flexibility, Barkow contends that the effects of evolutionary adaptation, while experienced now, were created in a distantly past environment. Observed in certain animals, the ability to restrict birth rates is connected to maximizing parental investment where "total living space or resources are limited or in which without parental care no offspring will survive [or] by having no offspring at all". Western families, too, once acquired this convenient ability: "Apparently[sic], our own ancestors lived with an ecology in which it maximised inclusive fitness to limit offspring and at times even to have none" (Barkow, J.H., ref. 4, p. 9).
12. See Wilson ref. 1, pp. 685–686. The studies Wilson cites, in addition to the adequacy of their authors' training, have been called into question. One place to start is Robert B. Edgerton's *Sick Societies: Challenging the myth of primitive harmony*, The Free Press, New York, pp. 6–8, 1992. See also Ik people | wikipedia, accessed 7 Oct 2022.
13. The response: academic vigilantism and the political significance of sociobiology, *BioScience* **26**(3):183,187–190, Mar 1976. Gould, in a later, more irenic, review of Wilson's work, still uncompromisingly pointed out Wilson's flawed arguments. See Gould, S.J., Biological potential vs biological determinism, *Natural History Magazine*, May 1976; in: Caplan, ref. 2, pp. 343–351. Peter Singer also threw his hat into the ring and, siding with Wilson, argued that "sociobiology does not necessarily lead to biological determinism. On the contrary, because we are beings capable of knowing the consequences of our actions and choosing accordingly, we can play tricks on evolution. Sociobiology can contribute to the success of our trickery by telling us more about what evolution is up to; the better we understand evolution, the better we can outfox it." Singer, P., Ethics and sociobiology, *Philosophy and Public Affairs* **11**(1):40–64, Winter 1982; p. 61.
14. Wilson, ref. 1, pp. 686–687. According to Leeds and Dusek, this obfuscation riddles sociobiology's apologetics: "Sociobiologists assert a strong biological determinism in human nature both in their technical work and in speaking to popular audiences. When challenged by their critics, they shift to a notion of 'tendency' or 'propensity'. When criticized still further, they claim that culture is '10% biological and 90% social', which is hardly informative. At times, they retreat to the claim that biology is a necessary but not a sufficient condition for culture, a claim which the critics could agree with. But of course, this last claim would make sociobiology vacuous and hardly the basis for the more daring theories and claims." (Ref. 1, p. xviii. References provided in original.)
15. Wilson, E.O., *Biophilia*, Harvard University Press, Cambridge MA, p. 121, 1984. Some incipient pre-Wilsonian hint of this Social Darwinism is found in ethologist Niko Tinbergen's work. He concludes that the solution to man's ethical problems is to do "our utmost to return to a reasonable population density [and] we must pursue the biological study of animal behavior for clarifying problems of human behavior of such magnitude as that of our aggression, and of education." Tinbergen, N., On war and peace in animals and man, p. 96; in: Caplan, ref. 2. Tinbergen's piece was originally published in *Science* **160**(3835):1411–1418, June 28, 1968.
16. Wilson, ref. 1, p. 21.
17. The Apostle Paul alludes to this poles-apart worldview, writing, "while we were still helpless, Christ at the right moment dies for the ungodly. Why, it is scarcely conceivable that any one would die for a simply just man, although for a good and loveable man perhaps some one here and there will have the courage even to lay down his life' but God gives proof of his love to us in Christ's dying for us while we were still sinners" (Romans 5:6–8).
18. Meta-ethics is the philosophical study of the semantic concepts, judgments, arguments and epistemological criteria involved in ethics. Contrary to normative ethics, it does not tell you what ought to be done; e.g. whether it is actually moral or immoral to abort a baby. Rather, it analyzes the logic and meanings of the terms used in an argument concerning the morality of abortion.
19. Nagel had obviously seen the problem when he remarked that "It is usually a good strategy to ask whether a general claim about truth or meaning applies to itself. Many theories, like logical positivism, can be eliminated by this test." Nagel, T., *The Last Word*, Oxford University Press, Oxford, p. 15, 1997.
20. Ruse, M. and Wilson, E.O., Moral philosophy as applied science, *Philosophy* **61**(236):173–192, Apr 1986; p. 186.
21. As Hilary Putnam pointed out, according to the Positivists, "the 'scientific method' exhausts rationality itself, and testability by that method exhausts meaningfulness" (Putnam, H., *Reason, Truth and History*, Cambridge University Press, Cambridge, p. 105, 1981).
22. Paraphrasing another philosopher, Ayer, despite his allegiance to logical positivism, comments that "the man who is ready to prove that metaphysics is impossible is a brother metaphysician with a rival theory of his own" (Ayer. A.J., *Language, Truth and Logic*, Dover Publications, NY, p. 34, 2014 (1946)).
23. Putnam, H., Why Reason can't be Naturalized, *Synthese* **52**(1):3–23, Jul 1982; pp. 18. Often we must read between the lines to identify a veiled positivist epistemic. William Casebeer writes, "Only the most stalwart anti-naturalist would think that facts about human beings and how they reason have absolutely no bearing on normative concerns, and only a small number of contemporary moral philosophers have taken this position [and] we can at least maintain that the biological and cognitive sciences can constrain moral theorizing by identifying the realistic limits of our biological and moral capacities" (Casebeer, W., *Natural Ethical Facts: Evolution, connectionism, and moral cognition*, The MIT Press, Cambridge MA, p. 33, 2003). Read in isolation, Casebeer's words seem impartially reasonable. However, his project is dedicated to a marriage of Deweyian pragmatism and Aristotelian virtue ethics undergirded by a maximizing of evolutionary considerations. Positivism by another name!

24. I am in no way suggesting evolution *is* science and, under the appropriate conditions, I cannot agree, by definition, that one discipline cannot inform the other. I only present Gould's criticism for the sake of my argument against evolutionists' claim that science always trumps questions integral to matters of religion. Similarly—and I don't think too many people would have a problem—I take a very broad view of religion to the extent that it is more than adequately up to the task of covering morality as a subdiscipline. In fact, religion has a long, venerable, and continued tradition of being the only epistemically viable and relevant vehicle to convey moral truths. Of course, Gould's comment must be cast against the fact that he was a staunch opponent of sociobiology.

25. Non-cognitivism maintains that there are no stance-independent ethical facts denoting objective right and wrong. Something of the vagueness and person-centred lack of objectivity inherent in non-cognitivism can be gathered from the following version of this meta-ethic. Gilbert Harman explains: "According to impartial spectator theories, to say that an action is wrong is to say that it is the sort of action that impartial spectators would disapprove of under conditions that are further specified in various ways in different versions of this sort of theory. Jane believes Albert was wrong, because she finds herself disapproving of his conduct and believes this disapproval is based on a knowledge of the facts and is not the result of some special stake she has in the matter at hand. We can explain Jane's disapproval of Albert's conduct by treating it as an instance of a more general regularity. Jane disapproves of Albert's action because it is the sort of act that spectators tend to disapprove of and Jane is the relevant sort of spectator. In other words, the act has certain properties which incline informed impartial spectators to disapprove of the act, and those properties incline Jane to disapprove of the act in much the way they incline other informed impartial spectators to do so. Since the action's wrongness consists in its being of a sort of which spectators in general disapprove, there is a sense in which Jane believes Albert's action is wrong because of the wrongness of that action" (Harman, G., Moral explanations of natural facts—can moral claims be tested against moral reality? *The Southern J. Philosophy* **24**(S1): 57–68, Spring 1986; p. 65). Although it is of little relevance, Albert's 'crime' was that he loved to torture cats. Swap out animal cruelty and substitute the unwarranted taking of human life (let's call it abortion), then on Harman's impartial spectator criterion, it's awfully difficult to eliminate any one actor's not having a stake in the issue (and which meta-impartial spectator will decide who's in and who's out?). And how do you, and who will, weigh up the rather nebulous 'knowledge of the facts'?

26. Wilson, ref. 1, p. 16. The full statement is: "Scientists and humanists should consider together the possibility that the time has come for ethics to be removed temporarily from the hands of the philosophers and biologicized" (p. 701). Michael Ruse has echoed Wilson's scientism by imploring that a "naturalistic approach [to ethics] means … one puts oneself in the hands of scientists. These would include primatologists, students of comparative cultures, game theorists, evolutionary psychologists, economists" (Ruse, M., 'Is Darwinian Metaethics Possible (And If It Is, Is It Well Taken)?'; in: Boniolo, G. & De Anna, G., *Evolutionary Ethics and Contemporary Biology*, Cambridge University Press, Cambridge, p. 14, 2006.

27. Ruse and Wilson, ref. 20, p. 179.

28. Ruse and Wilson, ref. 20, p. 186. Arguably Ruse's most infamous iteration of this meta-ethic is from his seminal *Taking Darwin Seriously: A naturalistic approach to philosophy*: "morality is a collective illusion foisted upon us by our genes … the illusion lies not in the morality itself, but in its sense of objectivity" (Basil Blackwell, Oxford, p. 253, 1986). His chimeric speculation certainly fits the bill for having his ethical cake and eating it too! I examine Ruse's meta-ethics in greater detail in an upcoming paper.

29. Ruse and Wilson, ref. 20, p. 188. And what about normative ethics? Can sociobiology say anything about what the good act is? Carla Kary sees sociobiology in almost religious terms, crediting it with the ability to 'redeem' normative ethics. See Kary, C.E., Sociobiology and the redemption of normative ethics, *Monist* **67**(2):161–166, Apr 1984. Convinced that moral philosophy is incapable of any fruitful or intelligent insight into its commission, Kary believes that sociobiology has reinvigorated moral philosophy to the degree it "seems capable of reaffirming the hope men have had in looking to moral philosophy for the answers to moral quandaries" (p. 161).

30. Ruse and Wilson, ref. 29. I think it's important to respond to their quasi-delusional epiphany that materialism is more congenial for moral behaviour than, say, a Christian one. In 2015 the Chinese government, an entity about as materialist as one could imagine, annulled its one child policy. Good news—at least for this present generation of young people starting out in married life. The bad news that accompanied this announcement was so simple and yet so shocking it takes you some time to come to terms with it. In the three plus decades of this policy, the Chinese government ordered the murders of up to 400 million of its unborn. Throw in the tens of millions of adults who died under Mao and what you have is the single biggest example, by far, of a philosophy's ability to cause more harm to the citizens of the country that promulgates it than has ever happened before. Materialism, the very belief that Ruse and Wilson have extended to the West, has killed more than anyone, yet these two either live in a state of mendacious denial or they just don't care.

    This Ruse- and Wilson-type turbid 'exculpation', involving a thorough inversion of the historical facts, is eloquently summed up by Roger Scruton. In his masterful book-length attack on materialism and its Marxist-inspired academics, he writes that "all those mystifying technicalities have the purpose of confiscating reality from our ordinary human understanding" (*Fools, Frauds and Firebrands: Thinkers of the New Left*, Bloomsbury Continuum, London, p. 275, 2019). Attacking the disingenuous rationalization for the impossible-to-comprehend atrocity numbers perpetrated under materialist ideology, such as the French Revolution, Mao's Great Leap Forward, and the like, Scruton, commenting on one Leftist justification for the murders, stated, "Crime … isn't crime, if the goal is utopia … . The statistics are irrelevant … reduced to the square root of minus one—a purely imaginary number … . In the urgent need to believe, to find a central mystery that is the true meaning of things and to which one's life can be dedicated, nonsense is much to be preferred to sense. For it builds a way of life around something that *cannot be questioned*. No reasoned assault is possible against that which denies the possibility of a reasoned assault. And thus it is that utopia stepped again, unchallenged, into the place vacated by theology" (*Ibid.*, pp. 258, 268, 271).

31. Kitcher, P., *Vaulting Ambition: Sociobiology and the quest for human nature*, The MIT Press, Cambridge, MA, pp. 241–243, 1985. Despite its amusing title, see a completely serious critique of Wilson's thesis in Falk, D., Is sociobiology neophrenology?; in: Leeds and Dusek, ref. 1, pp. 109–118.

32. See Kitcher's entire eighth chapter in ref. 31 for a detailed address of these issues, including a (cautiously) worthwhile discussion attacking Wilson's support for homosexuality as natural.

33. Kitcher, ref. 31, pp. 418–419.

34. Kitcher, ref. 31, p. 421. Alasdair MacIntyre defined emotivism as "the doctrine that all evaluative judgements and more specifically all moral judgments are *nothing but* expressions of preference, expressions of attitude or feeling, insofar as they are moral or evaluative in character" (*After Virtue*, University Of Notre Dame Press, Notre Dame, IN, pp. 11–12, 2007). As Trueman critically notes, "emotivism is a theory not of meaning but of use … emotivism presents preferences as if they were truth claims" (Trueman, C.R., *The Rise and Triumph of the Modern Self: Cultural amnesia, expressive individualism, and the road to sexual revolution*, Crossway, Wheaton, IL, p. 85, 2020). Note Trueman's analysis of the homosexual marriage debate in the USA, the proponents of the legal cases aimed at overthrowing the Defence of Marriage Act and how emotivism was "used polemically to dismiss arguments for DOMA" (p. 309, but also pp. 302–315.) On an interesting side note, Trueman writes that MacIntyre argued that the Bloomsbury Group's philosophical guru, G.E. Moore, was the man most responsible for promoting emotivism (p. 86). Bloomsbury was an egregiously decadent and sexually immoral London Bohemian group. One of the leading figures in Bloomsbury was the author Virginia Woolf. Woolf was the great-granddaughter of James Stephen, a true evangelical and an abolitionist. Leslie Stephen, E. Michael Jones writes in his chapter, Homosexuality as subversive, that Woolf's father, Leslie Stephen, "lost his faith in the 1860s as a direct result of the publication of Darwin's Origin of Species … . His solution to the problems that loss entailed was to turn religion into an ethos" (*Degenerate Moderns: Modernity as Rationalized Sexual Misbehavior*, Ignatius Press, San Francisco, CA, p. 57, 1993).

35. Kitcher, ref. 31, p. 422.

36. Kitcher, ref. 31, p. 424.

37. For a tight but comprehensive overview of the different versions and the implications of utilitarianism see Moreland, J.P. and Craig, W.L., *Philosophical Foundations for a Christian Worldview*, InterVarsity Press, Downers Grove, IL, pp. 433–444, 2003. Thomas Nagel remarks that, under utilitarian considerations, "Everyone is treated equally as a source of inputs to the calculation of value, but once that is done, it is total value rather than equality that takes over as the goal [and that it] may have problems supplying a usable common measure of well-being for combinatorial purposes." Contrasted with this is a Kantian categorical approach, so that such "accords to everyone not equality of input into the totality of value, but equality of status and treatment in certain respects" (Nagel, T., *The Last Word*, Oxford University Press, NY, p. 123, 1997).

38. Kitcher, ref. 31, p. 423.

39. Readers may wish to begin by looking at articles at CMI, for example, God and logic | creation.com, and Sproul, R.C., *Not a Chance: The myth of chance in modern science and cosmology*, Baker Books, Grand Rapids, MI, pp. 149–164, 1994.

40. Kitcher also makes a sophomoric oversight by calling Hume's Is-Ought Fallacy the Naturalistic Fallacy. See ref. 31, pp. 428–431. I explore these two paralogisms in greater detail in an upcoming part, but, suffice for now, Kitcher correctly notes Wilson's lapse in logic by deriving a prescriptive 'ought' from a descriptive or factual 'is'. The Naturalistic Fallacy, championed by G.E. Moore, working in an opposing direction, is critical of attempts to reduce the (moral) good to any natural property or thing.

41. Rawls, J., *A Theory of Justice*, Belknap Press, Cambridge, MA, 2005 (revised from the original 1971 publication).
42. In this regard it resembles the Prisoner's Dilemma I discussed at length in part 4. Rawls is an idealist and has been appropriately criticized for his pie-in-the-sky theory of justice. Despite his use of Rawls, Kitcher does raise one epistemological problem for Rawls' account, namely a need to respond to the following: "Why should the conclusions reached by parties in an ideal situation, the original position, prove binding on actual people?" (Kitcher, ref. 31, p. 433). Rawls attempts to counter this and other criticisms in his lengthy paper titled 'Kantian Constructivism in Moral Theory' (*J. Philosophy* **77**(9):515–572, Sept 9, 1980). However, it's abundantly clear that Rawls is single-mindedly intent on considering only naturalistically informed beliefs, though not necessarily undergirded by science, psychology, or social theory. To this end he writes, "The search for reasonable grounds for reaching agreement rooted in our conception of ourselves and in our relation to society replaces the search for moral truth interpreted as fixed by a prior and independent order of objects and relations, whether natural or divine, an order apart and distinct from how we conceive of ourselves … . Apart from the procedure of constructing the principles of justice, there are no moral facts" (p. 519). I guess the best way to sum up his project is to describe it as a book-length rationalistic thought experiment. For some general criticisms of Rawls' idealism and his Enlightenment-dependent credo that political liberalism would dissolve "men's propensity to injustice", see Berkowitz, P., *Virtue and the Making of Modern Liberalism*, Princeton University Press, Princeton, NY, pp. 24ff, 1999. Interestingly, for a contemporary atheist, Rawls believes, among other things, that intact two-parent families bring the best rewards for the public good.
43. Kitcher, ref. 31, p. 434.
44. Kitcher, ref. 43. Kitcher dismisses God solely, so it seems, on the presumed efficacy of Plato's Euthyphro problem. I deal with this in an upcoming part.
45. Kitcher, P., Ethics and evolution: how to get here from there; in: de Waal, F., *Primates and Philosophers: How morality evolved*, Princeton University Press, Princeton, NJ, pp. 136–137, 2006.
46. I hope my whole-hearted scepticism is overlooked, but it is clearly obvious that telling a, or any, good story, in the hope that something sticks, is not a historical account. After all, Wilson believes sociobiological explanations are the ultimate, life-forming myth and "the best myth we will ever have" and "the only mythology that can manufacture great goals from the sustained pursuit of pure knowledge." Wilson, E.O., *On Human Nature*, Harvard University Press, Cambridge, MA, p. 207, 1978.

    As Burian pointed out, Wilson's theory is entirely flexible: "The power of the theory resides in the richness of the explanatory stories it allows, the system of retreats to alternative stories ... . To put the point cynically: it becomes a highly amusing parlor game to see who can devise the best evolutionary account showing how an arbitrary chosen behaviour could have become fixed in a given population." Burian, R.M., A methodological critique of sociobiology, p. 382, in: Caplan, ref. 2. Also note Burian's swipe at Wilson's understanding of the rise of altruism, though this can quite easily be directed to any evolutionist's belief on the matter: "Are we really supposed to believe that the first Good Samaritan appeared as a rare mutant" [p. 180 of Wilson's book] and that kin and group selection preserved the fortunate mutation?" (p. 379). The key, I may suggest, is Wilson's inclusion of the evocative 'Imagine'. Elsewhere Burian lays out in detail the conceptual confusion Wilson and his followers have regarding the very nature of altruism. Burian also points out that Wilson ignores that population genetics, rather than fixing alternative alleles, eliminates them, thus making it impossible for the 'Imagine' to be even imagined!
47. Epigenetic rules have been suggested. I address this solution, so-called, in an upcoming part. These 'rules' are granted an undeserved ontological status out of philosophical exigency, rather than one based on empiricism. I argue that they're really not much more than a disingenuous surrogacy, a non-material theoretical replacement for the work that soul or non-reductive mind, the non-material entity, achieves.
48. Flanagan, O.J. Jr., Is morality epiphenomenal? The failure of the sociobiological reduction of ethics, pp. 211, 213; in: Leeds and Dusek, ref. 1. Bizarrely, but perhaps not unsurprisingly, one of Flanagan's disparate ethical precepts he cites from Khomeini's legal code is "the dietary laws covering sodomized ewes" (p. 211).
49. Burian, R.M., A methodological critique of sociobiology; in: Caplan ref. 2, p. 383.
50. Wilson, ref. 1, pp. 715–716. His American Marxist critics' disquiet arose from, accurately or otherwise, sociobiology's perceived genetic determinism which erased the liberal idea of man's freedom. In other words, they visualize man as something special in nature. The irony is that Christians have proposed the same starting value about man, yet, to the unregenerate person, it is greeted with howls of derision because of affording man his special place in the universe based on their axiomatic undergirding that man is made in the image of God. Other critics have noted the fallout from the weakening of Christianity's objective morality. Although favourable to many of sociobiology's claims, Bernard Davis points out that with the loss of the transcendent moral realm, specifically due to evolution's undermining it, there is no longer moral consensus, and moral relativism seems to be the default position. See his guarded criticisms in Davis, B.D., A middle course between irrelevance and scientism, pp. 315–318; in Caplan, ref. 2. Davis's piece was originally published in the Hastings Center Report, October 1976.
51. Wilson, ref. 46, pp. 155–157. For further criticism of Wilson, see Gould, S.J., Biological potential vs biological determinism, pp. 343–351; in: Caplan, ref. 2; Allen, E. *et al.*, Against 'sociobiology', pp. 259–264; in: Caplan, ref. 2; Sociobiology study group of science for the people, sociobiology—another biological determinism, pp. 280–290; in: Caplan, ref. 2; and Lewontin, R.C., Sociobiology—a caricature of Darwinism, *PSA: Proceedings of the Biennial Meeting of the Philosophy of Science Association* **1976**(2):22–31, 1976. For a response to these criticisms, see Ruse, M., Sociobiology: a philosophical analysis, pp. 363–368; in: Caplan, ref. 2. For an in-depth, critical analysis of Wilson's use of, *inter alia*, kin selection, reciprocal altruism, and group selection, see Edelman, M., Human behavior and sociobiological models of natural selection, pp. 1–42; in: Leeds and Dusek, ref. 1.
52. See, for example, Courtois, S. *et al.*, *The Black Book of Communism: Crimes, terror, repression*, Harvard University Press, Cambridge MA, 1999.
53. Wilson, ref. 1, p. 704.
54. Fischer, D.H., *Historians' Fallacies: Toward a logic of historical thought*, Harper Perennial, Harper Collins, New York, p. 56, 1970. Wilson provides a sterling example of this fallacy. Drawn to illustrate "the threshold of autocatalytic social evolution two million years ago", his artist's 'speculative reconstruction' includes all the apposite information which would convince even the most recalcitrant that this is a historical snapshot. His account tells what these 'men' were doing (foraging for food and "driving rival predators from a newly fallen dinothere"); their prey's status ("succumbed from exhaustion or disease, its end perhaps hastened by attacks from the animals closing in"); what was on the sidelines and how they reacted ("a female sabertooth cat (*Homotherium*) and her two grown cubs have been at least temporarily intimidated and are backing away. Their threat [*sic*] faces reveal the extraordinary gape of their jaws."); the height of these two-million-year-old men ("quite small, less than 1.5 meters"); and the non-participating animals ("The herbivore populations were dense and varied, as they are today. In the left background are seen three-toed horses (Hipparion), while to the right ... "). (Wilson, ref. 1, p. 711.)
55. Caplan, A.L., Say it just ain't so: adaptational stories and sociobiological explanations of social behavior, p. 153; in: Leeds, A. and Dusek, ref. 1.

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The design of bacterial flagella: part 1—flagellar design in model organisms

David Thomas

For over two decades, the bacterial flagellum has been used as an example of design by the biblical creation and Intelligent Design communities after it was popularized by Michael Behe in *Darwin's Black Box*. Scientific knowledge of bacterial flagella and their associated systems has proliferated in recent years. This prolific knowledge is mainly due to recent advances in cryo-electron microscopy which have allowed us to visualize protein complexes at, or near, atomic resolution using an electron microscope. However, most of these discoveries have not been discussed in the creationist or Intelligent Design literature. This review will bring the reader up to date on these discoveries and will cover not just flagellar motors, but also their many associated control systems. Part 1 will look at the design of the flagella of the model organisms *Escherichia coli* and *Salmonella enterica*. Specifically, part 1 will focus on the function, atomic architecture, and design features of each of their parts. These parts come together to form a truly spectacular molecular machine.

> "When Antony van Leeuwenhoek looked through a single-lens microscope in 1676 and observed man's first recorded glimpse of bacteria, it was their motion that most delighted him: 'I must say, for my part, that no more pleasant sight has ever yet come before my eye than these many thousands of living creatures, seen all alive in a little drop of water, moving among one another, each several creature having its own proper motion.'"[1]

Bacterial movement has fascinated researchers since their discovery by the biblical creationist and father of microbiology Antonie van Leeuwenhoek.[2] At the scale of bacteria, water is like ultra-thick honey, since viscous forces dominate over inertial forces (represented with a low Reynolds number[3]). When a bacterium stops powered motion, it comes to a complete stop in less than a 10^{th} of the diameter of a hydrogen atom.[3] Despite this, bacteria swim through water incredibly quickly with one species reaching over 200 body lengths per second.[4] This is equivalent to a human swimming at 1,224 km/hr.

In the early 1970s, it was discovered that bacteria swim using nano-scale rotary motors that rotate long filaments that function as propellers.[5] The bacterial flagellar motor was popularized as an example of irreducible complexity by Michael Behe in his 1996 book *Darwin's Black Box* and has since become an icon of the Intelligent Design (ID) Movement. Scientific knowledge of bacterial flagella has proliferated in the last decade, due, in part, to cryo-electron microscopy (Cryo-EM). This technology has allowed researchers to image large protein complexes at, or near, atomic resolution using an electron microscope. The main advantages of Cryo-EM over X-ray crystallography is that Cryo-EM does not require the proteins to be crystallized and can capture large protein complexes *in situ*.[6]

Most of these recent discoveries have not been discussed in the creationist or ID literature. This review will bring the reader up to date on these discoveries and will cover not just flagellar motors, but also their many associated control systems.

This is a seven-part review (see table 1).

General information on bacterial flagella

- Bacterial flagella are typically divided into three main sections: a rotary motor, a helical propeller, and a universal joint which connects the motor to the propeller (figure 1).
- The motors are powered by the electrochemical potential (chemiosmotic/pH gradient) across the cell's cytoplasmic membrane and can be almost 100% efficient, depending on the conditions.[7]
- The fastest flagellar motor has been recorded at 102,000 rpm, which is ~8.5 times faster than a Formula One racing car engine.[8]
- Flagellar motors can change gears to change rotation direction, power output, fuel type, motor speed, and/or sensitivity to signals from the cell's navigation system (see parts 3 and 4).
- *E. coli's* bacterial flagellum is made of at least 27 proteins, each present in a few to tens of thousands of copies (table 2). In *E. coli*, over 12 other flagellar-associated proteins are required for flagellum assembly and regulation but are not part of the flagellum itself (table 2).
- Bacteria, archaea, and eukarya all include species with flagella, but their flagella each have radically different designs (figure 2).
- Bacterial flagella are just one of multiple different machines that bacteria use to move, most of which appear to involve a rotary motor.[9]

Table 1. Content of each part of this review

Part	What is covered
1	Design of the flagella in the model organisms *Escherichia coli* and *Salmonella enterica* (from now on, *E. coli* and *Salmonella*, respectively)
2	Diversity of flagellar designs across bacterial species, including the number and arrangement of flagella, the function of flagella, and the structure of flagella (of both core and additional parts)
3	Motility behaviour of bacteria and how flagellar motors change gears
4	Navigation systems that control flagellar motors, including chemotaxis systems
5	Gene regulation in flagellar-chemotaxis systems and how this controls construction of flagella and chemotaxis systems
6	Step-by-step mechanisms of how flagella and chemotaxis systems are constructed, including control mechanisms beyond gene regulation
7	Theoretical origin and evolution of flagellar-chemotaxis systems and an argument in favour of the creation/design explanation

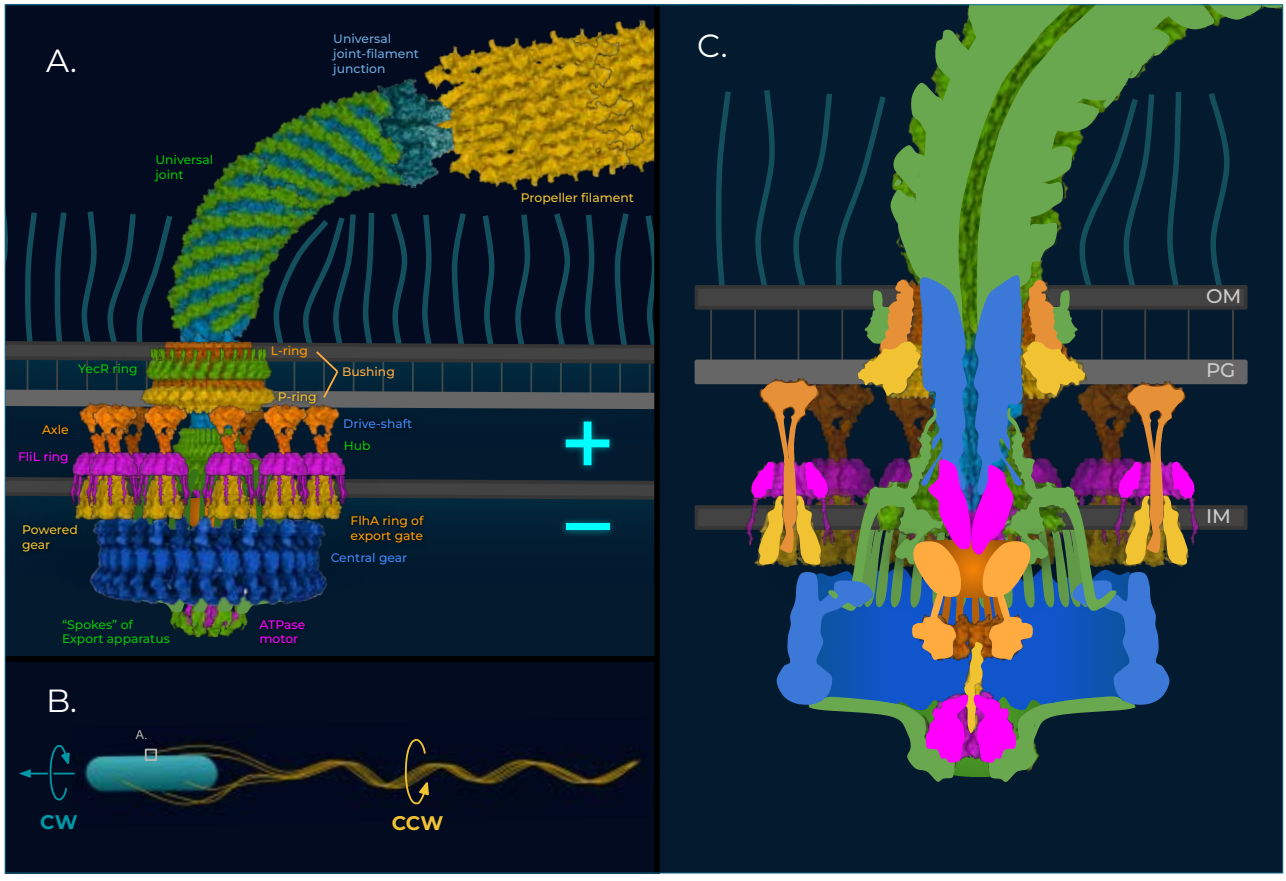

Figure 1. Bacterial flagellum of *E. coli*. (A) Representative illustration of *E. coli's* flagellar motor, which is near identical to *Salmonella's* flagellar motor. Illustration includes protein structures from *E. coli*, *Salmonella* and other species as well as Alphafold predictions[48,49] when the structure in *E. coli* has not yet been solved experimentally. The + and - symbols indicate the relative charge difference across the inner membrane of the cell. Labels are colour-coordinated to label the component closest to each label of the same colour (apart from the universal joint which is coloured green and blue but has a green label). (B) Illustration of a swimming *E. coli* cell showing the coordinated rotation of the propeller filaments. The blue arrows indicate the movement of the cell body and the yellow arrow indicates the rotation of the flagellar filaments. As well as propelling the cell forward, the CCW rotation of the filaments causes the cell to rotate CW. The square labelled 'A'. indicates the location of the close up shown in A. (C) Illustrative cross-section of *E. coli's* flagellar motor, coloured the same as in A (apart from the universal joint which is coloured green). The export apparatus located inside the motor can clearly be seen in this cross-section (see figure 9). OM: Outer membrane; PG: Peptidoglycan layer (cell wall); IM: Inner membrane. Unless stated otherwise, protein structures in all figures are sourced from the RCSB protein data bank[50] or the Alphafold protein structure database.[48,49] Protein graphics are made in part using Mol*.[51] The illustrations sometimes contain only parts of the cited PDB structures. The illustration of the central gear used in figures 1a, 2c, 3a, 6 and 7b is after Carroll *et al.*,[52] used with permission. The illustration of the universal joint-filament junction used in figures 1a, 2c and 21b is after Green *et al.*,[38] used with permission.

Table 2. Parts list for *Salmonella* and *E. coli* flagellar motors and their associated systems[10]

Common name(s) of part (alternative name)	Number of units*(Protein name$_{\text{number present}}$)	Function
Stator/torque-generating unit (powered gear and axle)	11*(MotA$_5$, MotB$_2$)	Converts electrical energy into kinetic energy (generate torque)
C-ring/switch complex (central gear)	33/34*(FliG, FliM, FliN$_3$)	Changes motor rotation direction. Transmit the torque of the powered gears to the central axis of the motor
FliL ring	11*(FliL$_{10}$)	Stabilizes the motor under high torque
Export gate	FliP$_5$, FliQ$_4$, FliR, FlhB, FlhA$_9$	Sorts and exports subunits to their assembly sites higher up in the flagellum
ATPase motor	FliJ, FliI$_6$	Unfolds and transports subunits to the export gate
Spokes	FliH$_{\text{unknown}}$	Hold the ATPase motor in place and stabilize the central gear
MS-ring (hub)	FliF$_{33/34}$	Connects the central gear, driveshaft, and export gate
Proximal rod (proximal driveshaft)	FliE$_6$, FlgB$_5$, FlgC$_6$	Transmits torque from the hub to the universal joint
Distal rod (distal driveshaft)	FlgF$_5$, FlgG$_{24}$	Transmits torque from the hub to the universal joint
P-ring (bushing)	FlgI$_{26}$	Stabilizes the rotation of the driveshaft
L-ring (bushing)	FlgH$_{26}$	Stabilizes the rotation of the driveshaft
YecR ring	YecR$_{26}$	May regulate the attachment between the outer membrane and the L-ring
Hook (universal joint)	FlgE$_{\sim 120}$	Changes the axis of rotation of the flagellum
Hook-filament junction (universal joint-filament junction)	FlgL$_{11}$, FlgK$_{11}$	Connects the universal joint to the filament
Filament (propeller)	FliC$_{>10,000}$, FljB$_{>10,000}$ (FljB only in *Salmonella*)	Exerts force on the surrounding fluid or substrate to move the cell
Filament cap	FliD$_5$	Assembles the filament
Flagellar proteins which are not part of the flagellum itself		
Master regulator	FlhD$_4$, FlhC$_2$	Activates Class ii flagella genes
FlgI chaperone	FlgA$_{\text{unknown}}$	Helps assemble the P-ring
Hook scaffold protein	FlgD$_5$	Assembles the hook
Hook length control	FliK$_{\text{many}}$	Controls hook length
FliO	FliO$_{\text{unknown}}$	Helps assemble the export gate
FlhE	FlhE$_{\text{unknown}}$	Unknown
Anti-sigma28 factor	FlgM	Inhibits Sigma28 (FliA)
FlgK/FlgL chaperone	FlgN	Binds to FlgK and FlgL
YdiV inhibitor	FliZ	Indirectly activates Class ii flagellar genes
Sigma28	FliA	Activates Class ii flagellar genes
FliD chaperone / anti-FlhDC factor	FliT	Binds to FliD and FlhC
Flagellin chaperone	FliS	Binds to Flagellin
FlgJ	FlgJ	N-acetylglucosaminidase
Chemotaxis proteins	Tar, Tap, CheR, CheB, CheY, CheZ, CheA, CheW	Form the chemotaxis system

Design of the parts

The similarities between flagellar motors and human-designed motors are simply astounding. Flagellar motors have many parts which perform similar functions to parts in human-designed motors, including gears, rotors, axles, driveshafts, bushings, ball-bearing–like bearings, brakes, clutches, structural scaffolds, hinges, universal joints, other joint types, adapter rings, sockets, switches, stators, capacitors, channels for fuel to flow through, mechanical sensors and components which respond to signals from the navigation system and other control systems.

The most studied bacterial flagella are those of the model organisms *E. coli* and *Salmonella*, which will be discussed below. Their differences will be pointed out when needed.

Gears

The gearbox of the motor is a 'two-cogwheel gear system'[11] (figure 3b) with a large central gear, surrounded by, and driven by, one or more smaller powered gears (figure 3a). The powered gears are powered by the electric voltage and chemical potential (difference in H^+ concentration) across the inner lipid membrane of the cell. This membrane functions as a capacitor by storing this electric voltage (and chemical potential), which is generated by other machines in the cell.

Each powered gear is made of five copies of a protein called MotA. These form a bell-shaped ring which rotates around an axle made of two copies of MotB (figures 4–5). The MotAB assembly is often called a stator or a torque-generating unit. The shape on one side of MotA matches the shape of the other side, like interlocking 3D puzzle pieces, allowing adjacent MotA subunits to tightly interlock. They interlock at a specific angle such that five of them form a ring. A band around the outer surface of the powered gear is hydrophobic, which keeps it positioned at the correct height in the lipid membrane (figure 4c).

MotB has three sections: the lower section functions as the axle inside the powered gear, the upper section functions as an anchor which attaches to the peptidoglycan cell wall, and the middle section functions as a tether between the axle and the anchor.[12] The axle is made of two alpha helices (one from each subunit) which twist around one another to form a coiled-coil structure which is the right diameter to fit inside the central hole of the powered gear.

The binding of protons to aspartate residues on the axle induces conformational changes which produce thrust. Based on the current evidence, protons flow through a stator complex through two channels between the axle and the powered gear. The movement of protons through these channels causes two aspartate residues on the outside of the axle to switch back and forth in a series of power strokes that each rotate the powered gear clockwise (when viewed from outside the cell) ~36°.[13] Based on detailed structural analysis, stators appear to use a sophisticated ratchet mechanism to prevent counterclockwise rotation.[14] Each power stroke is induced by the binding of one proton with each powered gear using 20 protons per rotation.[15] Each rotation step closes one channel and opens the other, resulting in a sequential operation. Thus, the 'stator' is itself a tiny rotary motor which powers the rotation of the larger components of the flagellum. This has been one of the most surprising discoveries in this field in recent years, because it was previously believed that the hub (MS-ring) and central gear (C-ring) formed the rotor, while the MotAB complex formed the stator. We now know that MotA forms the rotor and MotB forms the stator.

The tether section of MotB includes a region just above the axle called the 'plug region'. This region can plug the two proton channels through the powered gear, effectively turning it off (see part 3).

At the base of the powered gear, the five MotA subunits form five gear 'teeth'. Each tooth has specific amino acids at specific positions to form electrostatic interactions with specific amino acids at specific positions on the gear teeth of the central gear (figure 3c). The rotation of the powered gears drives the rotation of the central gear through these electrostatic interactions, analogous to man-made, contactless, magnetic gears.[16] It is not yet clear if the teeth of the gears are positioned in an interlocking orientation (tooth-to-gap) or if they line up tooth-to-tooth.[17]

If our current understanding is correct, the powered gears must rotate at 122,400 rpm in *E. coli* to drive the central gear at the measured speed of 18,000 rpm.[18] How these components can rotate so rapidly without forfeiting the integrity of the membrane remains to be solved.[19]

The central gear, commonly called the 'C-ring', is made of three stacked sections (figures 6–7; figures 1–26 are available here). The top section is made of FliG, which has three domains: the N-terminal domain connects to the hub; the middle domain connects to the middle section of the central gear; and the C-terminal domain forms the gear teeth (figure 7c). The middle section is made of FliM and changes confirmation to change motor rotation direction (see part 3). The lower section is made of FliN and the C-terminal of FliM and forms a coiled-coil structure (figure 7b–c).

The gear box of flagellar motors cannot function properly under high torque without a third important component of the gearbox—the FliL ring (figure 8).[20] In 2022, it was discovered that FliL forms a ring around the powered gears in *Helicobacter pylori* and *Borrelia burgdorferi* to stabilize them under high torque.[21,22]

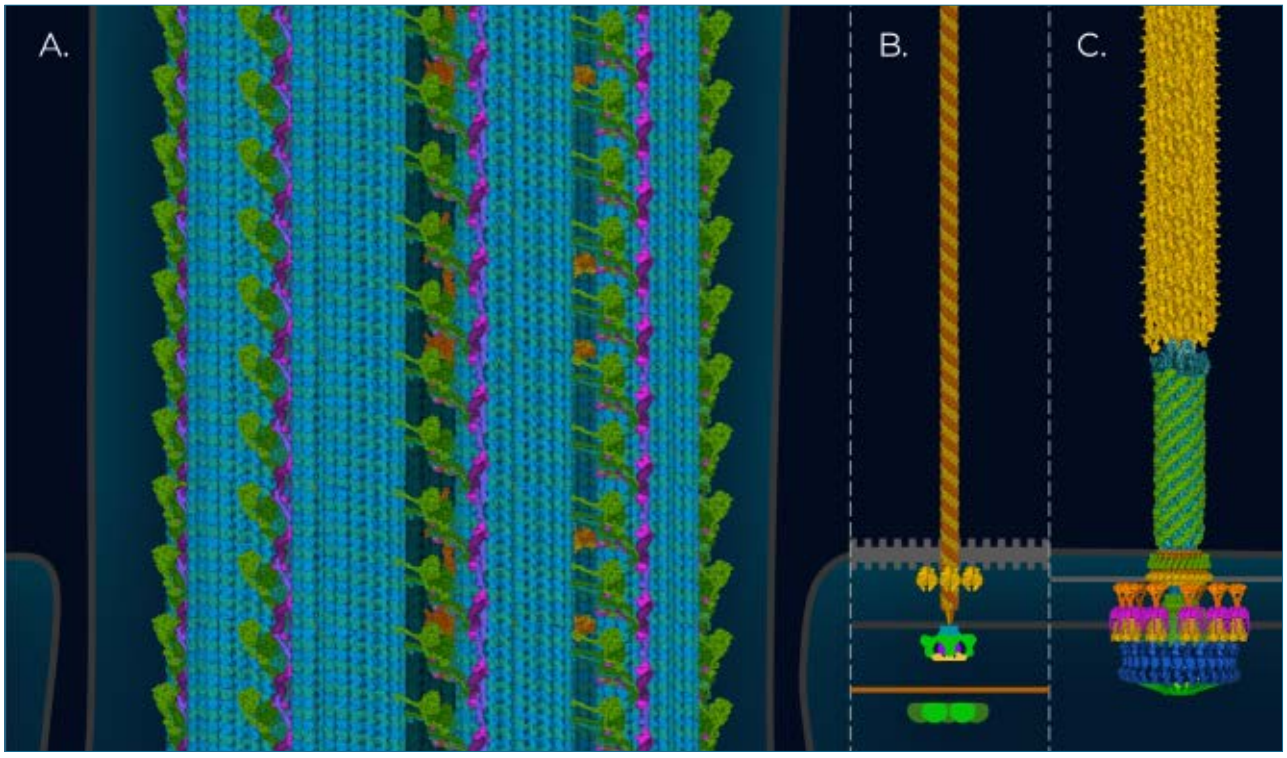

Figure 2. Comparison of flagella in eukarya (A), archaea (B), and bacteria (C). The universal joint of the bacterial flagellum is shown in a straight orientation for illustrative purposes and does not represent the wild-type structure of the universal joint. The archaeal flagellum is powered by ATP and has a propeller filament (PDB ID: 5TFY[53]) that is assembled from its base like a pilus, in contrast to bacterial flagellar filaments which are assembled from the tip (PDB ID: 4ZBH[54] is shown at archaellum base). The eukaryotic flagellum is by far the most complex, being made of over 400 different proteins that form an assembly of microtubules (shown in blue, PDB ID: 7RRO[55]), dynein (shown in green, PDB ID: 7K58[56]) and other components (shown in other colours, PDB ID: 7JTK[57]). Unlike archaeal and bacterial flagella, eukaryotic flagella do not rotate but sway side to side. See the caption of figure 1 for image credit for C.

Export apparatus

Sitting inside the central gear and hub is a molecular machine called the export apparatus. The export apparatus has three components: an export gate, an ATPase motor, and a ring of spokes (figure 9). Since this apparatus is involved in the construction of flagella, its design will be discussed in part 6.

Hub

The hub (figures 10–11), commonly called the MS-ring, has a remarkably complex structure, especially considering that it is made of a single type of protein called FliF. The hub is a ring complex made of 33 copies of FliF and sits in the inner membrane.[23] The hub forms the connection between the driveshaft, central gear, and export gate. In mechanical terms, the central gear and hub can together be called the 'transmission'.

FliF likely has 6 domains, though its complete structure has not yet been solved. At the top of the hub is a beta-collar called the 'socket', which houses the base of the driveshaft. The upper section of the socket has a smaller diameter than the lower section, which prevents the driveshaft from slipping out (figure 10c).[24] Around the base of the socket is an outer ring formed by domain RBM3. The C-terminal of FliF extends from the outer ring and hooks around the N-terminal domain of FliG to connect the hub and central gear (figure 11d).[25]

The socket and outer ring have 33-fold rotational symmetry to match the rotational symmetry of the central gear.[23] The central gear and hub can also have 34-fold rotational symmetry[26,25] (see part 4). The hub has an inner ring of 21-fold rotational symmetry, which has structural plasticity to mold to the irregular helical shape of the export gate which it holds in place.[27] Consequently, the inner ring functions as a symmetry adapter between the rotational symmetry of the outer ring and the helical symmetry of the export gate. Another component of the hub forms a rotational symmetry adapter ring, linking the outer ring, with 33-fold rotational symmetry, and the inner ring, with 21-fold rotational symmetry. Remarkably, the inner ring and adapter ring are both made of the same domain of FliF, RBM2, but

are derived from different subunits (figure 11a–c): Of the 33 RBM2 domains present in the structure, 21 form the inner ring, nine form the adapter ring, and the locations of the remaining three are unknown.[23] (When the hub contains 34 RBM2 domains, 22 form the inner ring while 10 form the adapter ring,[23] or, according to another study, 23 form the inner ring while 11 form the adapter ring.[25]) The subunits around the hub therefore fold into different conformations to form these different structures (figure 11b–c). For this design to work, the RBM2 domains must have the appropriate binding sites and shape to form both the inner ring and the adapter ring. The hub's design, with multiple different rings of different symmetries all forming from a single type of protein, explains a long-unresolved mystery in the field as to why the hub and central gear had observed differences in their rotational symmetry.

The RBM1 domains and N-terminals of FliF likely extend from the base of the adapter and inner rings to form a ring around the FlhA ring of the export gate (figures 1c, 9, 11d).[23]

Driveshaft

Torque is transmitted from the hub inside the cell to the universal joint outside the cell via a driveshaft which passes through a bushing (a type of bearing) (figure 12). At the start of 2021, the atomic structure of the driveshaft and bushing was not known. Then, in April, May, and July 2021, three separate teams of scientists published the atomic structures of the driveshaft and bushings of *Salmonella*.[24,27,28] Below are their findings.

The design of the driveshaft, often called the 'rod', is anything but simple (figures 13–14). The proximal driveshaft has 17 subunits (6 FliE, 5 FlgB, and 6 FlgC), while the distal driveshaft has 29 subunits (5 FlgF and 24 FlgG). The proximal driveshaft slots on top of the export gate inside the hub socket and strongly attaches to both. The distal driveshaft is thicker and sits inside the bushing. The driveshaft subunits form 11 rows, called 'protofilaments', which twist in a left-handed helix.

The driveshaft must be strong, straight, and highly rigid to efficiently transfer torque from the hub to the universal joint. It also experiences a lot of mechanical stress and so must be highly reinforced to prevent it from breaking apart. The inner layer of the driveshaft and the outer layer of the distal driveshaft are both highly reinforced in specific directions to provide strength and rigidity. Each subunit in the driveshaft is precisely shaped to tightly interlock and forms extensive connections with adjacent subunits.[24] The Dc domains of FlgG in the upper distal driveshaft extend downwards and connect to the subunits in the lower distal driveshaft (FlgG and FlgF) and the proximal driveshaft (FlgC). This tightly connects the distal and proximal driveshafts and tightly connects the inner and outer layers of the structure. The inner layer is made of alpha helices which slot together like tiles on a roof.

The proteins that form the distal driveshaft are shaped in such a way that when they interlock, they leave a small hole between them in the outer layer. In the lower portion of the distal driveshaft, these holes are filled in with a section of the FlgG subunits called the 'FlgG specific sequence' (labelled GSS in figure 14b), which interacts with the three surrounding subunits (figure 13a). This reinforces the lower distal driveshaft. However, in the upper portion of the distal driveshaft these holes are not filled in because the universal joint subunits do not have the GSS region (figure 14b). This makes the upper portion of the distal driveshaft slightly more flexible. This likely makes for a smoother transition between the rigid lower distal driveshaft and the flexible universal joint, which would allow for more efficient torque transmission between these components.

The driveshaft is at risk of breaking apart from the hub and export gate due to the mechanical strain experienced under high torque. To prevent this, it is strongly attached to the hub and export gate in multiple different locations (figure 15a). The proximal driveshaft slots into the top of the export gate (figure 15d). Alpha helices from both components grip onto grooves on the adjacent component.

The proximal driveshaft also attaches to the inner surface of the hub socket. FliE alpha helices bind to the lower inner surface of the hub socket, while FlgB binds to the upper inner surface of the hub socket (figure 15d). These subunits have flexible adapter regions which allow them to function as adapters between the hub with rotational symmetry and the driveshaft with helical symmetry.

The hub also connects to the proximal driveshaft. Peptide loops with regions called 'L1' and 'L2' extend out of the top of the hub socket from each of the FliF subunits. Five of the L1 regions bind into grooves in the proximal driveshaft while five of the L2 regions bind into open pockets in the proximal driveshaft (figure 15b–c). Flexibility in the FliF loops allows them to bind at different heights around the helical driveshaft, allowing them to also function as symmetry adapters between the hub and driveshaft.[27]

Bushing

The distal driveshaft rotates inside a cylindrical structure which functions as a bushing (figures 12, 16–18). The bushing is made of two rings called the 'L-' and 'P-rings'. The P-ring sits in the cell wall, surrounds the lower distal driveshaft and is made of 26 interlocking FlgI subunits. The L-ring sits in the outer membrane, surrounds the upper end of the distal driveshaft and is made of 26 interlocking FlgH subunits. The inner surface of the bushing and the

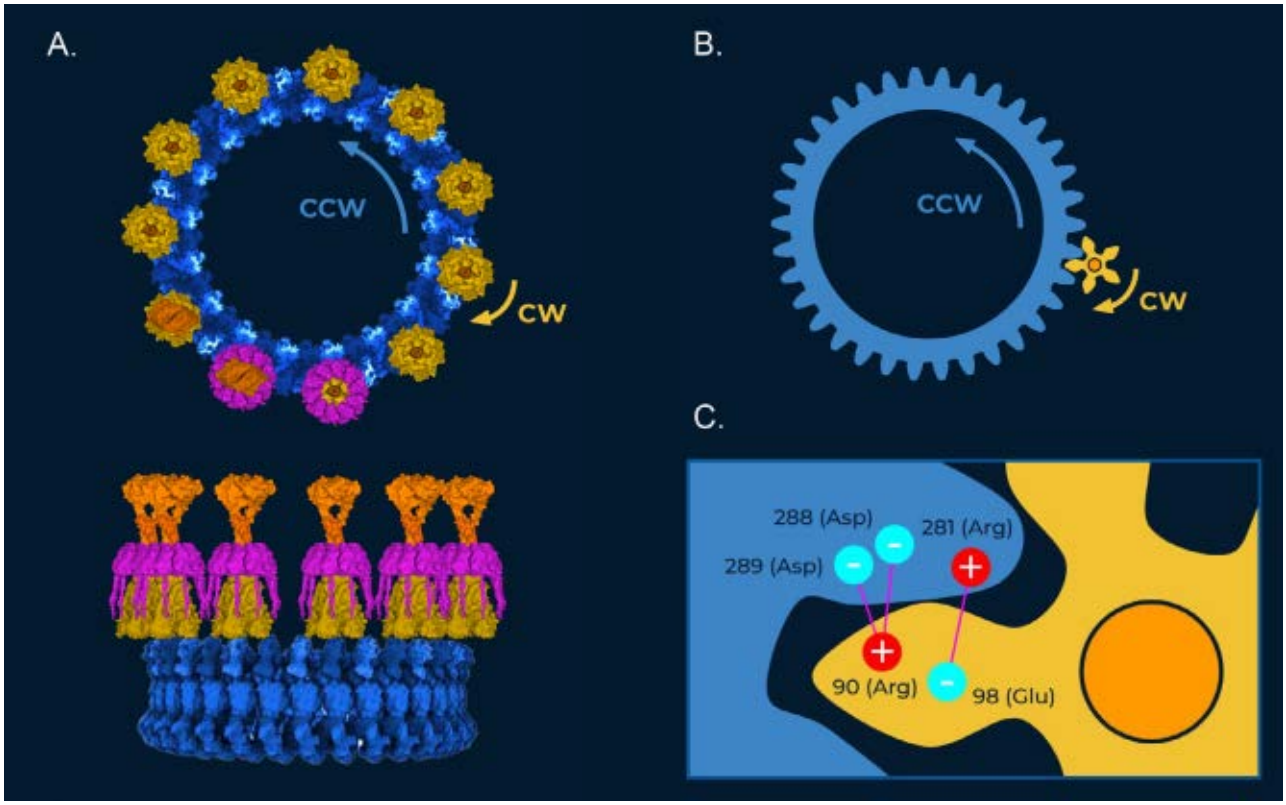

Figure 3. Representative illustration of the gearbox of the flagellar motor of *E. coli* and *Salmonella* in forward gear at full power. (A) Molecular surface representation of the gearbox viewed from the top (top) and side (bottom). In the top view, one MotA powered gear is shown with the cell-wall binding domain of MotB (shown in orange), one with the FliL ring (shown in purple) and one with both. The rest of the power gears are shown only with the axle domain of MotB (shown in orange). See the caption of figure 1 for image credit. (B) Diagram of a two-cogwheel system with a gear ratio of 34:5. (C) Residues involved in electrostatic interactions between the central gear and powered gears. Residue numbers correspond to sequences in *E. coli.* It is possible that the gear teeth are not in an interlocking orientation but are oriented with the gear teeth of the power gear positioned directly above the gear teeth of the central gear.

outer surface of the distal driveshaft are each very smooth, "indicating that these two structures are optimally designed for free rotation of the [driveshaft] inside the LP ring without much friction."[28] This smoothness is remarkable when compared to the typically bumpy surface of proteins.

The P-ring is made of three subrings corresponding to the three domains of FlgI (figure 17). The P-ring is highly reinforced with tight connections between the three subrings and between adjacent subunits. The inner subring of the P-ring (made of domain D1) forms a water-tight seal around the distal driveshaft. This seal contacts the distal driveshaft at a knife-edge to greatly minimize friction. To further minimize friction, this knife-edge seal is believed to form a ring of hydrogen bonds with the distal driveshaft which "allow[s] the P ring to act as a ball bearing to stabilize the central localization of the [driveshaft] in the P ring and enable rotation of the distal [driveshaft] without significant structural obstacles or energy consumption."[24] The symmetry mismatch between the driveshaft and P-ring (helical and rotational, respectively) further reduces friction, allowing the driveshaft to rotate more smoothly.[27]

The gap between the bushing and driveshaft must be small enough to stop fluids leaking out of the cell but large enough that the bushing does not grip the driveshaft too tightly. This is an insanely small margin for error. The gap between the knife-edge seal of the P-ring and the distal driveshaft is less than the diameter of a carbon atom (< 0.34 nm).[29] Thus, the diameter of the driveshaft and bushing are fine-tuned with atomic-scale accuracy. To get this level of accuracy, the subunits that make these parts must have a precise shape, width, and binding angle to form a helical tube or ring, respectively, with the right diameters.

The bottom section of the distal driveshaft is made of FlgF, instead of FlgG, and has a diameter that is slightly larger than the diameter of the hole through the bushing. This "precisely coordinates the position of the [driveshaft]"[24] within the bushing by reducing vertical sliding of the driveshaft.

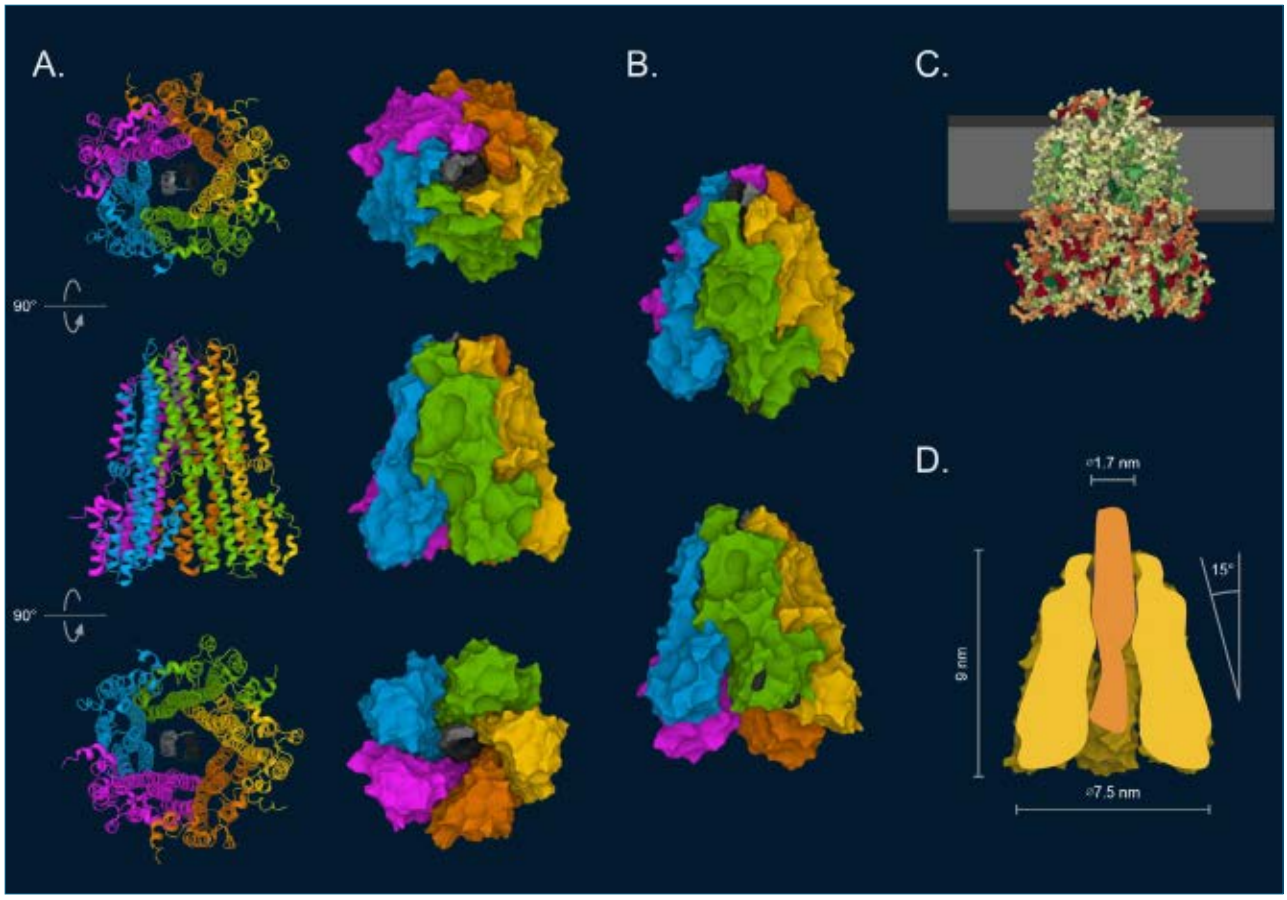

Figure 4. The MotA powered gear of *Bacillus subtilis* (PDB ID: 6YSL[13]), which is expected to be very similar to that in *E. coli* and *Salmonella*. (A) The ribbon diagram (left) and molecular surface representation (right) of the MotA powered gear. The MotB axle is shown in light and dark gray. (B) Isometric views of MotA powered gear. Residues that form electrostatic interactions with the central gear (90 and 98 in *B. subtilis*) have been coloured dark gray on the green MotA subunit. (C) Hydrophobicity of residues (red = hydrophilic; green = hydrophobic). The approximate positions of the hydrophilic and hydrophobic portions of the cytoplasmic membrane have been shown in dark gray and light gray, respectively. (D) Illustrative cross-section of MotA powered gear (yellow) and MotB axle (orange).

The outer perimeter of the P-ring is designed to tightly attach to the cell wall. This is necessary to fix the bushing in place. The L-ring must be strongly attached to the top of the P-ring to hold it in the correct position and alignment around the driveshaft. Thus, each subunit in the L-ring binds to four subunits in the P-ring.[24]

The L-ring has three layers. The inner two layers form a beautifully elegant double-layered beta sheet cylinder (figure 17b). The beta strands in the two layers are angled at 85° to one another to form a strong lattice structure with cross-links between the layers. Each subunit in the L-ring intricately interlocks with six adjacent subunits to form a very mechanically stable structure.[28]

For proper function, the L-ring must connect to the outer membrane. Around the top of the L-ring is a hydrophobic band made of two rings of alpha helices (figure 18a,c). The third layer is made by the N-terminal of FlgH. The tip of the N-terminal has a fatty acetyl group attached which inserts into a hydrophobic gap between the alpha helices in the lower ring of alpha helices. This forms a tighter connection between the L-ring and outer membrane. A membrane-bound, lipidated protein called 'YecR' binds around the outside of the L-ring and is believed to regulate the attachment between the outer membrane and the L-ring (figure 18).[27]

A band around the top of the inside of the L-ring is strongly negatively charged, which repels the negatively charged distal driveshaft. This is believed to stabilize the central position of the distal driveshaft as it rotates.[24] In contrast, the knife-edge seal of the P-ring is positively charged and is thus attracted to the negatively charged distal driveshaft, which may be important for the construction of the P-ring around the distal driveshaft (see part 6).

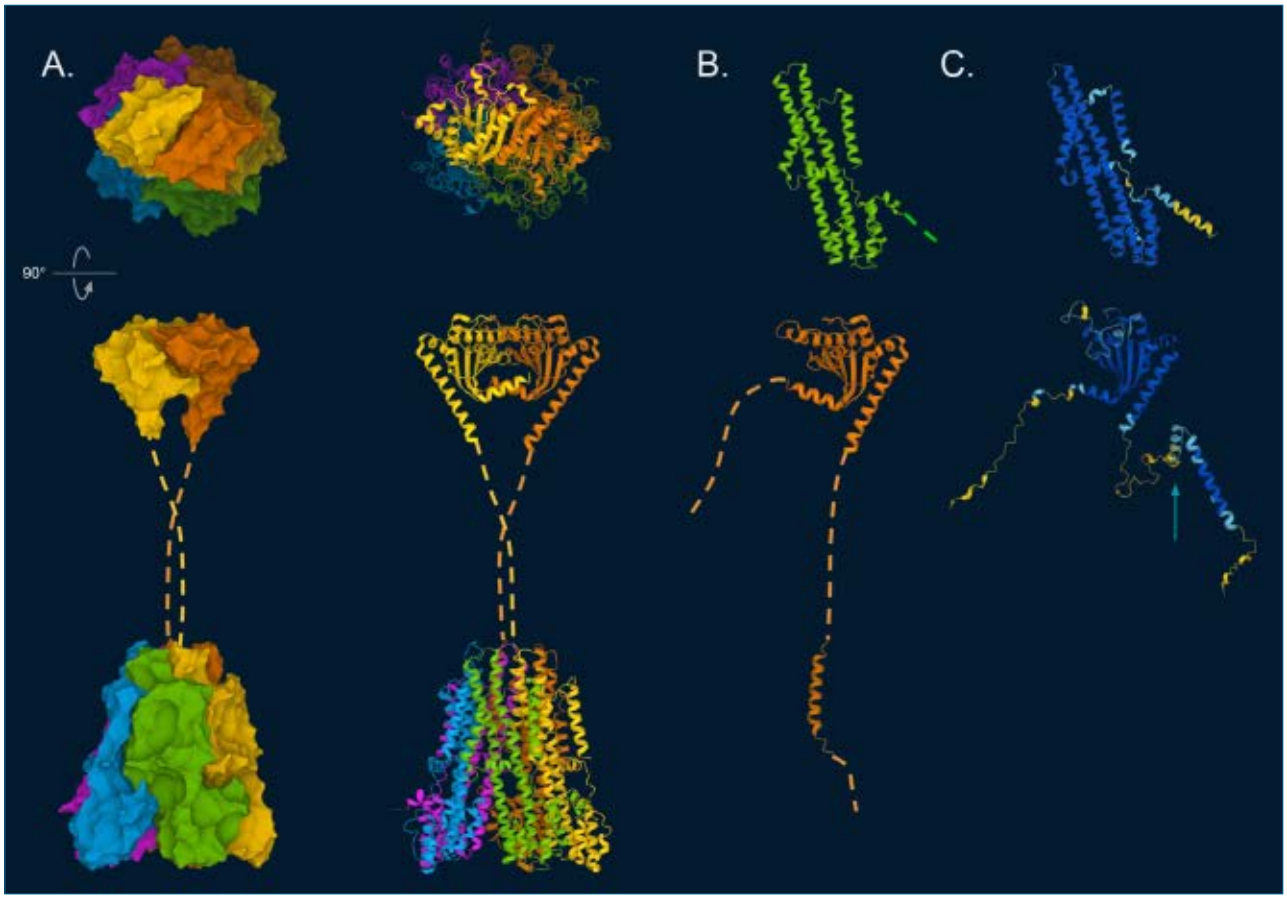

Figure 5. The MotAB complex of *Bacillus subtilis*. (A) The molecular surface representation (left) and ribbon diagram (right) of the MotAB complex. MotA subunits (PDB ID: 6YSL) shown in blue, green, yellow, orange and purple, respectively. MotB subunits (PDB IDs: 2ZVY[58] & 6YSL) shown in yellow and orange, respectively. (B) The solved structure of MotA (upper) and MotB (lower). The dashed lines indicate portions of the structures that have not been solved experimentally and are likely unstructured (apart from the plug region). (C) The Alphafold prediction of MotA (upper, P28611) and MotB (lower, P0AF07), showing portions of proteins not yet solved (dark blue = very high confidence in prediction accuracy, orange = very low confidence). The blue arrow points to the plug region of MotB.

Universal joint

Torque is smoothly transmitted from the driveshaft to the propeller filament using a sophisticated universal joint (figures 19–20). The sophistication of this joint surpasses what was expected even by ID advocates.[30] Unlike the driveshaft, which must be rigid, the universal joint must be longitudinally flexible and rotationally rigid (easy to bend but hard to twist), placing significant constraints on its design.

The universal joint, composed of approximately 120 FlgE subunits, forms a curved structure with three tubular layers, each possessing distinct mechanical properties.[31,32] The three layers are made of the four domains of FlgE (the middle layer is made of two domains, D1 and Dc). The domains are each quite rigid but have flexible hinges between them.[33] These hinges allow each side of the universal joint to smoothly expand and contract as it rotates. The smooth compression and extension is guided by dynamic changes in the interactions between adjacent subunits, allowing the structure to flex with minimal energy cost.[32,34]

When the motor is operating at full speed, the sides of the universal joint in *E. coli* expand and contract approximately 300 times per second.[35] Yet, even at such high speeds the universal joint can smoothly and efficiently transmit the torque from the motor to the propeller filament.

The inner layer has a very similar design to the inner layer of the driveshaft. The middle layer forms a mesh-like structure which is reinforced in three different helical directions.[32] This gives the universal joint its necessary rotational rigidity and strength, while still allowing longitudinal flexibility.[33] The outer layer forms a six-stranded helical structure that resembles a spring.[32] Each domain in the spiral tightly interacts with adjacent domains around the spiral for mechanical support.

Since the hook experiences high mechanical strain, it is intricately attached to the driveshaft to prevent breakage (figure 20c). Also, the Dc domains of the universal joint hook under the subunits in the distal driveshaft (they hook into the holes between the driveshaft subunits but do not have the GSS region to fill the holes and so do not provide rigidity).[24] This tight connection between the driveshaft and universal joint allows for efficient torque transmission between them.

The length of the universal joint is optimized to 55 ± 6 nm.[31] It is believed that if the universal joint were too long, it would buckle and cause the flagellar filament bundle behind the cell to be less stable, making the cell body wobble and swim less efficiently. Alternatively, if it were too short, it would be too stiff to function as a universal joint.[36]

The universal joint must possess sufficient flexibility to accommodate the large change in axis of rotation while also maintaining rigidity to prevent breakage under significant hydrodynamic stress. To solve this, when the hydrodynamic forces on the propeller filament increase, the universal joint automatically stiffens to reduce the bending angle.[37] This allows the universal joint to fine-tune its stiffness in response to solution thickness, necessary for efficient, high-speed swimming.

Universal joint–filament junction

The universal joint–filament junction connects the flexible universal joint to the more rigid propeller filament (figure 21).[31] It comprises two adapter rings made from FlgK and FlgL, respectively.[38] Its complete atomic structure is yet to be solved.

Propeller filament

The final component of the flagellum, not including the filament cap, which is used during construction and stays attached at the tip, is the filament (figures 22–25). The driveshaft, universal joint, universal joint–filament junction, and the filament are collectively referred to as the 'axial components' (figure 26a). This contrasts with the torque-generating units, central gear, hub, and bushing, which are referred to as the 'ring components' (figure 26b).

When rotated counterclockwise, the long screw-shaped filament propels the cell forward (figure 1b). In *E. coli*, each filament is made of tens of thousands of FliC subunits, is about 20 nm wide and 15 µm long.[39] *Salmonella* alternates as to whether its filaments are made of FliC or FljB every few generations in a process called 'flagellar phase variation' (see part 5).[40] The outer domain of FljB is more flexible than that of FliC and allows for closer to optimum motility under viscous conditions.[41] Collectively, flagellar filament proteins are referred to as 'flagellin'.

The core of the filament structure is a rigid, highly reinforced double-layered tube.[42] Like the driveshaft and universal joint, the filament is made of 11 twisted protofilaments.

To function as a propeller, the filament must form a rigid helix. It is no small engineering challenge to get a filament made of a single type of protein to form a supercoiled helical shape. It is believed that this is achieved by the protofilaments existing in two distinct conformations, with each protofilament able to flick between a contracted or expanded form.[34] If one side of the filament is contracted and the other is expanded, the filament is curved, and because the filament is also twisted, it forms a helix.

Three different types of interactions between the subunits are essential for this design to work: Firstly, 'permanent' interactions determine the geometrical constraints of the filament's architecture. Secondly, 'sliding' interactions allow subunits to slide past each other with minimal changes in interaction energy. Thirdly, 'switch' interactions stabilize the protofilament's two conformations.[34] Evidence indicates that the protofilaments are in an intricate balance between expanded and contracted forms and can rapidly flick between them.[39] Single point mutations can cause the protofilaments to be either all expanded or all contracted, which results in a non-motile mutant with straight filaments.[39] This places very tight constraints on the design of the filament.

The filament is not just a simple propeller: modifying how many protofilaments are contracted or expanded changes the helical pitch and diameter of the filament to form many different waveforms which are used during swimming and turning manoeuvres.[43] When a filament is rotated counterclockwise (looking from behind the cell), the torque exerted on the filament by the motor causes it to form a rigid left-handed helical shape, perfect for a propeller. However, when the filament is rotated clockwise, it forms a right-handed helix.

When all the filaments of a cell are rotated counter-clockwise, the filaments all come together in a coordinated bundle behind the cell, which propels the cell forward (figure 1b).[44] To form a smoothly rotating filament bundle without jamming, the filaments must rotate in phase with each other. The filaments use an elastohydrodynamic mechanism to do this.[45] The elastic properties of the universal joint and filament are crucial for this mechanism to work, without which the cells would be unable to swim straight.[45] When one or more filaments are rotated clockwise, they change their waveform, separate from the filament bundle and turn the cell in a new direction (see parts 3 and 4).[43]

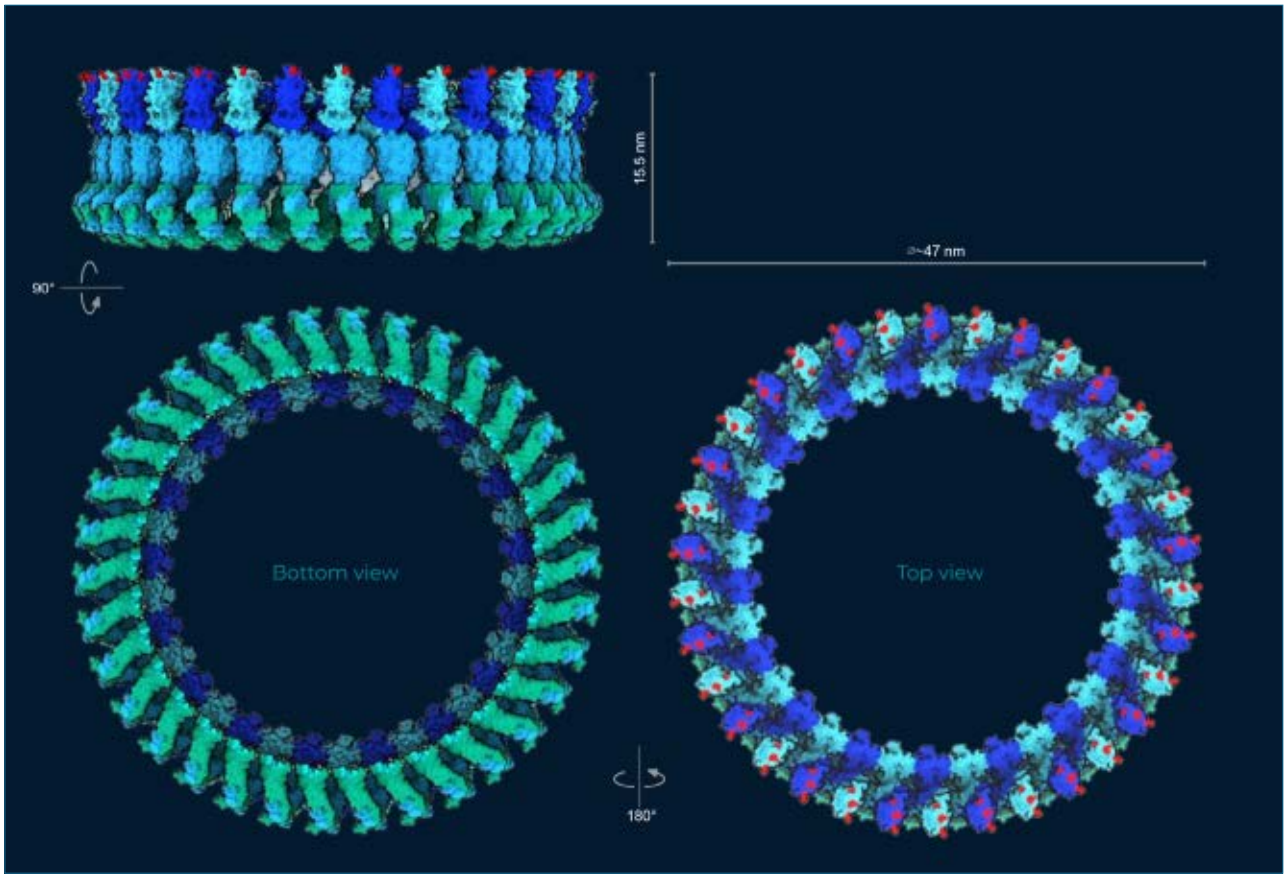

Figure 6. Orthographic projection of the predicted structure of the central gear (C-ring) of *Vibrio alginolyticus* which is believed to have a very similar structure to the central gear of *E. coli* and *Salmonella*. FliG is shown in dark blue and cyan, FliM is shown in light blue, and FliN is shown in green. FliG residues which form electrostatic interactions with MotA are shown in red. See the caption of figure 1 for image credit.

The design of the flagellar filaments has become even more remarkable with the discovery that the outer domains of FliC in some bacteria, including some *E. coli* strains, can form a beautifully complex sheath around the filament core with different symmetry to the core structure.[46] The outer domains can form tetramers (in the *E. coli* O127:H6, figure 22) or dimers (in the *E. coli* O157:H7, figure 23).[46]

Conclusion

Bacterial flagella are truly an engineering marvel; every minute detail of every part of these flagella is intricately and beautifully designed. Each part is not designed in isolation but is designed to work together with the other parts as a complete functioning whole. All of these parts, each with their own remarkable design features, come together to form a truly spectacular molecular machine.

Leeuwenhoek saw none of this, and yet I'm sure he would say, as he did in his day:

> "From all these observations, most plainly we discern the incomprehensible perfection, the exact order, and the inscrutable providential care with which the most wise Creator and Lord of the Universe has formed the bodies of these Animalcules … . And this … must surely convince all of the absurdity of those old opinions, that living creatures can be produced from corruption or putrefaction."[47]

Part 2 will explore the design of flagella from other species which are significantly more complex than those discussed here and contain many additional parts. As it turns out, the flagella of *E. coli* and *Salmonella* may be two of the simplest within bacteria.

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Enantiomeric amplification of L amino acids: part 1—irrelevant and discredited examples

Royal Truman

Naturalist explanations for the origin of proteins based on only L-amino acids (AAs) have concentrated on the notion of an initial enantiomeric excess (e.e.) being amplified. The processes discussed here couldn't plausibly have occurred naturally. Amplification examples include chemical reactions irrelevant for living organisms, like Soai alkylation and cyclobutene polymerization. Examples of selective adsorption on minerals such as kaolinite and montmorillonite clay have been discredited by other researchers. Adsorption on chiral calcite and quartz would have produced identical amounts of D and L enantiomers overall. Causing a specific glycine crystal face to extract only L-AAs from a racemic solution required pure D leucine be adsorbed on a different face. Cleverly designed AAs with large alkyl groups formed conglomerates of single enantiomer chains but the products remained inseparably mixed, and the molecules are not relevant biochemicals. Using a Langmuir trough to form crystalline islands of opposite handedness required chemical transformations and laboratory processes not found in nature. In all the proposals there is no credible reason why separated AA enantiomers would not remix. Furthermore, any e.e. produced would racemize in water over time and combine with already racemized AA in the environment.

Key biomolecules such as proteins, RNA, and DNA can only function if their constituent monomers use a single enantiomer (mirror image variant). Truman explained in this journal how secondary structures, the basis for protein-reliable folded structure, won't form if poisoned by merely c. 5% randomly inserted D-amino acids (AAs).[1] Goldanskii and Kuzmin also showed, using molecular models, how inserting a few L-sugar nucleotides in double-stranded helices prevents H-bonding across the two strands of DNA.[2]

D-amino acid residues are included in proteins in some rare cases, to add structural and functional diversification or to provide chemical robustness. This opposite chirality is produced through posttranslational conversion of an L → D residue and not by incorporating D-amino acids from the environment.[3]

Given their symmetry with respect to each other, it is often assumed that the physical and chemical properties of AA enantiomers would always be identical, preventing their separation under natural conditions. However, as we will see in this series, this intuition is not correct for all circumstances.

The error arises from failing to recognize that homochiral dimers (L-L or D-D) and heterodimers (L-D) won't experience identical physical interactions. Diastereomeric aggregates occasionally possess different physical properties after chemical bonding or even when non-covalent packing interactions are strong.

Creation scientists must not be careless and claim that racemic mixtures of AAs and sugars must always be found under natural conditions.

Chemists know that when amino acids and sugar molecules possessing chiral carbon atoms are synthesized in a laboratory racemic mixtures are obtained unless a suitable template is used. This could be an asymmetric enzyme, reagent, or catalyst.[4] But then the question becomes: where do these pure enantiomeric substances come from?

As far as I am aware, no specialist in the Origin of Life (OoL) community argues that a prebiotic earth contained only L-AAs, which therefore would have had to be used when forming peptides. The current naturalist approach consists of trying to explain two complementary processes. In Process 1 discussed in detail below, an initial enantiomeric excess of the L isomer ($e.e._L$), defined by equation (1), is assumed to have been somehow produced.

$$e.e._L = ([L] - [D] / [L] + [D]) \quad (1),$$

where [L] and [D] are the concentration of each enantiomer.

After an initial e.e. has been produced, somehow Process 2 is assumed to have locally concentrated, or amplified, this excess. For L to be concentrated in one location, it must automatically be depleted from where it was extracted. The total amount of L remains unchanged. A key assumption is that the two nearby regions do not remix.

In this series, I will be focusing on Process 2 and showing that none of the proposals that I am aware of could have had an effect of any relevance for OoL purposes and, in most cases, couldn't plausibly have occurred naturally without intelligent guidance.

It is important to distinguish between natural conditions and expertly guided outcomes. Louis Pasteur was able to

physically separate two versions of hemihedral crystals formed from a racemic mixture of sodium ammonium tartrate by selecting each using a lens and tweezers.[5] In addition to the willful choice being made hundreds of times to separate both kinds of crystals, formation of these kinds of crystals is very difficult even when carefully guided in a laboratory by professional chemists.[6]

An important and recurring principle in this series is that any $e.e._L$ formed must be eventually made available in water to polymerize and form peptides. For example, if a technique produces solid crystals, then in this state they cannot contribute to an OoL model, since the subsequent necessary chemical processes would not occur. They must be first dissolved. In a series of papers, Truman argued that for thermodynamic and kinetic reasons, AAs in water would racemize faster than elongate to form large peptides, at all temperatures under natural conditions.[1,7–9] In all the experiments discussed in this current series, the conditions were optimized to shorten the time needed and to yield high enantiomeric excesses. Arguing that this was only for researcher convenience and that less optimal natural settings would be compensated for by enormous time overlooks that the long time periods would have permitted loss of e.e. through L- → D-AA conversion.

Process 1. Creation of a small enantiomeric excess

I already analyzed potential sources of an initial $e.e._L$ in this journal, and only mention a few naturalist proposals here which are often found in the evolutionist literature or were not mentioned before.[1]

Parity violation

In nuclear physics, the weak interaction produces β-decay of atomic nuclei.[10] Unlike the other fundamental interactions (gravitation, electromagnetism, and the strong interaction), its effect is not perfectly symmetrical.[11] The tiny energy difference of $\approx 10^{-14}$ Jmol^{-1} theoretically could lead to $\approx 10^{-15}$ % ee_L in an AA.[12]

Another quantum mechanical computational method developed by Quack predicted a slightly higher value for ee_L of $\approx 10^{-14}$ % for alanine, valine, serine, aspartate, and glyceraldehyde.[13,14] Quack and others have denied an energy preference at all in the case of L-alanine.[13,14]

Since [L] + [D] = 1 from eqn. (1), an $e.e._L \approx 10^{-14}$ % means that [L] – [D] $\approx 10^{-16}$. The greater likelihood of a particular L-AA interacting with another L instead of D enantiomer is less than a specific hair on the head of one person on the entire earth being correctly matched to another hair selected by chance.[15] Longer peptides consisting of hundreds, or thousands of only L-AAs couldn't have formed based on such a probability.

Quack is aware that a few more L- than D-AAs, generated over billions of years, cannot explain the origin of proteins. The miniscule excess would racemize with enough time, anyway. He warns that[16]

> "The *de lege* (parity violation) community often expresses the belief that, because we know for certain that there is some preference at the molecular level that is caused by parity violation, there must 'somehow' be a connection to the evolution of biomolecular homochirality at the next higher level of organization. Such an argument can be easily refuted."

Electric, magnetic, gravitational, and centrifugal fields

Many papers have been published over the last century claiming that a way has been found to preferentially produce an AA enantiomer. Creation of chiral molecules has been claimed using electric, magnetic, gravitational, and centrifugal fields, but the alleged successful outcomes could never be independently confirmed, so too much time won't be devoted to these reports. In a review article, leading OoL researcher Bonner summarized all these claims by starting that

> "… to date no experimentally substantiated asymmetric reactions have been observed under the external influence of any of the fields described above (electric, magnetic, gravitational and centrifugal fields)."[17]

Bremsstrahlung photons

Ulbricht pointed out, in 1959, that longitudinally polarized electrons emitted during β-decay produce so-called circularly polarized 'bremsstrahlung' photons. He suggested that these might induce stereoselective photochemical reactions.[18] However, none of the experiments ever found chiral products beyond the limitations of experimental error.[17]

Over the following years, Ulbricht and Vester carried out a variety of experiments and concluded that

> "No unequivocal rotations (measured at the sodium D line) were obtained, and any induced optical activity was probably less than 0.02%."[19]

Process 2. Amplification of enantiomer excess

Autocatalytic amplification

The principle that 'once a little reactant or product is formed this could facilitate more being produced' is well known. Max Bodenstein introduced the concept of a chain reaction into the chemical toolkit in 1913.[20] His insight was that an unstable chemical intermediate might sometimes be generated, rich in energy, which, on further reaction, gives

rise not only to a particular final product, but also to another intermediate, which thereby regenerates the same process, over and over.

An example is the hydrogen with chlorine chain reaction to produce HCl shown in figure 1.[21]

A similar concept involves polymerizations which consist of multiple monomer components. Once polymers begin to form, they can react with monomers to form larger polymers of the same kind. Many examples and applications are found in the industry.[22]

One of the simplest examples involves the commercial production of aliphatic polyethers generated by the ring-opening polymerization of epoxide monomers (figure 2).[23]

The driving force is the high ring strain of epoxides. This enables polymerization of epoxide monomers via base-initiated catalysis, acid-initiated catalysis, or by coordination polymerization.[22]

Although the preceding discussion helps to understand the underlying intuition behind how a bootstrap set of reactions might lead to amplification *per se*, none refer to the phenomenon of enantioselectivity. The examples do help demonstrate, though, the implausibility of the effect arising naturally. For example, high concentrations of pure H_2 and Cl_2, in the absence of radical quenchers such as oxygen, are not expected to arise naturally. High concentrations of high-energy pure epoxides will not arise naturally either. But we will see in this series of papers that examples proposed by evolutionists to amplify initial e.e.s for biologically relevant compounds are also implausible under putative prebiotic conditions.

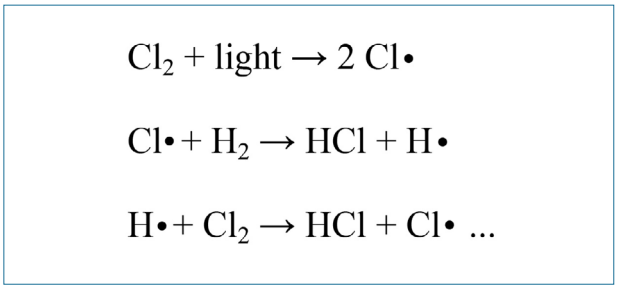

Figure 1. Hydrogen-chlorine chain reaction (from ref. 20)

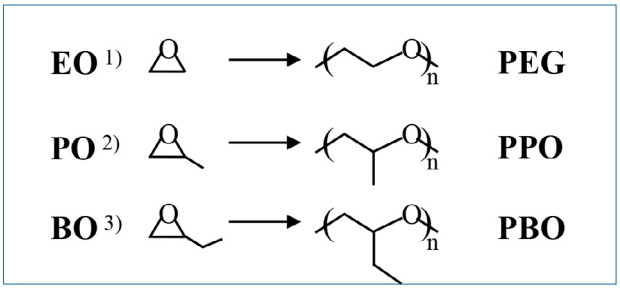

Figure 2. Polymerization of epoxide monomers (from ref. 22)
[1] EO: ethylene oxide
[2] PO: propylene oxide
[3] BO: butylene oxide

Autocatalytic amplification (Soai alkylation)

Frank proposed, in 1953, the theoretical concept of autocatalytic amplification reactions as a mechanism to produce e.e.[24] The only experimental corroboration ever found of this concept is the astutely designed and often mentioned Soai alkylation of pyrimidyl aldehydes (see figure 3).[3,25] Remarkably, if a small excess of one of the activated enantiomers is provided to the reaction mixture it can preferentially autocatalyze creation of more of that enantiomer. However, this involves chemistry that has no prebiotic relevance, given the consensus that such dialkylzinc compounds would not have been generated in a putative aqueous prebiotic soup, far less in a pure and concentrated amount.[3,26]

A theme which will recur repeatedly in this series is that interesting artefacts can be designed under extreme or narrowly-controlled laboratory conditions which will not occur naturally. They have no direct relevance for OoL purposes. The Soia scheme illustrates this. Three exceedingly rare chemicals with very unstable moieties and which will not be naturally produced must be present and kept isolated. They must be unable to diffuse away from each other. So, where would the steady influx of diisopropylzinc and pyrimidine-5-carbaldehydes come from to keep the reaction cycle going? And how would they be pumped into the isolated reaction environment? In addition, the solvent used was toluene or a mixture of ether and toluene, which are irrelevant for OoL purposes. Furthermore, after the repeated catalytic step, the final product required hydrolysis under acidic conditions.[28]

Nonetheless, the Soai reaction has kept hope alive in the OoL community since it

> "… proved that a chemical reaction exists in which very low enantioenrichment is amplified to almost enantiopure (>99.5% ee)."[28]

What is so special about the Soai reaction and what can be learned from it?

First of all, *autocatalytic reactions generally should not increase the enantiopurity of products.* Here is why.

Suppose that an asymmetric catalytic reaction led to a product having enantiomeric excess $e.e._{prod}$. In the ideal case where the catalyst is enantiopure ($e.e._{cat} = 1$) the product would have some enantiomer excess $e.e._0$.

For a simple catalytic reaction, $e.e._{prod}$ is a linear function of the $e.e._{cat}$:

$$e.e._{prod} = e.e._0 \times e.e._{cat} \quad [1]$$

Clearly, when $e.e._{cat} < 1$, *as is inevitably the case*, then $e.e._{prod} < e.e._{0}$.

Consider now what happens when this is an autocatalytic reaction starting with less than enantiopurity. The product formed will have a lower enantiomeric excess than its antecedent state. During each cycle the catalyst (which is also the product) would begin with a lower $e.e._{cat}$ than before. Over time the $e.e._{prod}$ would decrease relentlessly, converging to zero.

This led Dr Blackmond, a leading OoL researcher, to conclude that "any process of pure autocatalytic self-replication would lead inexorably to a racemic world!"[4]

But then why does the Soia reaction defy this expectation? To increase the e.e. through an autocatalytic scheme one enantiomer must somehow be able to suppress production of the other enantiomer.

This could happen in special cases when enantiomers *S* and *R* could interact to form *SS*, *RR* and *SR* dimers. Suppose *S* is present initially in excess. If *SR* is formed preferentially over the homodimers, then major enantiomer *S* would become enriched and relatively less *R* would participate in the self-catalysis.

Blackmond suggested a variant of this argument for the Soia reaction. Remarkably, the dimers and not the individual monomers seemed to be responsible for catalyzing the reaction, with the heterochiral *SR* being more effective than the *SS* or *RR* species. She pointed out that otherwise the product would have been racemic.[4]

The cleverly designed Soia scheme could only work in an exceedingly concentrated laboratory flask or the dimers would not form. Furthermore, more raw materials had to be added continuously at a rate which ensured autocatalysis faster than the end products could racemize naturally.

Autocatalytic inhibition (cyclobutane polymers)

Addadi and colleagues, from the Weizmann Institute of Science in Israel, devised a clever scheme to produce enantiomerically enriched chiral cyclobutane polymers from special dienes, which themselves are non-chiral.[29,30] Alignment between neighbouring C=C bonds led to two crystal versions, which, upon UV irradiation, yielded dimers, trimers, and higher oligomers, denoted by $[\ ]_d$ and $[\ ]_l$ in figure 4 in equal amounts. No net enantiomeric excess of product P_r or P_s was generated.

However, one of the crystalline variants was favoured when chiral dimers, trimers, or oligomers (i.e. P_r or P_s in figure 4) were present in excess during crystallization. In some experiments, the monomers were melted with 3–15% enantiomerically pure dimer, trimer, or oligomer and allowed to crystallize together. And in other experiments, crystallization was carried out using concentrated solutions in laboratory solvents (CH_2Cl_2, hexane, or ethyl acetate).[31]

Enantiomeric yields ranged from 30 to 100%, depending on the monomer used. Specifically, more D crystals were obtained when an excess of P_s was present, and more L crystals if the initial excess was of P_r.[28] Apparently one oligomer can replace several monomers at the growing site of a crystal having the same configuration, slowing down further crystallization. The authors showed that this kind of inhibition affects specific faces of crystals, modifying the rate of crystal growth and dissolution of that portion of the crystals.

This example shows that, at least in principle, autocatalysis of an enantiomer can be designed under carefully contrived conditions. In the final sentence of one paper, the researchers point out correctly that

> "The solution of the amplification problem will thus require very specially designed experiments."[30]

Experiments such as those described above illustrate the creativity and technical expertise of the thousands of researchers who have designed processes to isolate pure D-AAs. The fact that molecules structurally unrelated to AAs must be used is revealing. It demonstrates the decreasing lack of hope in finding a feasible naturalistic original for L-only AAs.

Nevertheless, creation scientists and ID supporters must avoid claiming that symmetry breaking can only occur with the help of pre-existing chiral enzymes. The next section summarizes why exotic designed systems like this one provide no evidence that L amino acids and D sugars could arise in enantiomeric purity under natural conditions. Although the objections are specific to this example, they are generally valid for most other schemes designed by OoL researchers.

Critique of these studies

Carefully designed schemes such as shown in figure 4 provide no evidence that pure L amino acids or D sugars could have been concentrated locally and naturally. This example cannot serve as a proof-of-principle, nor analogy, that e.e.s could have arisen without intelligent guidance for the following reasons:

- The materials displaying an enantiomeric excess have no resemblance to biochemical molecules used in living systems.
- The reactants are highly unlikely to be produced naturally under even speculative theoretical prebiotic conditions.
- The reactions are of very limited applicability. The stable inhibitor product required intense UV photolysis to produce an unusual cyclobutane ring having two possible enantiomeric configurations.

- The crystallization process required carefully guided conditions, including:
  - use of special laboratory solvents, since the reactants and products were not soluble in water
  - beginning with supersaturated pure solutions which were slowly cooled
  - control of pH, etc.
- Long exposure to UV light would have generated a variety of destructive radicals, but the researchers irradiated only D or L crystals at just the right time, wavelength, and duration to obtain the intended result.
- Extremely high concentrations of the pure dienes were necessary to form the crystals, at the same time and location.
- There is no reason why a significant excess of one inhibitor (P_r vs. P_s) would be present, and therefore the inhibitory effect would be symmetric, leading to no net enantiomeric excess.
- The effect was kinetically and not thermodynamically driven, and of only a short duration. Within only hours, the inhibitory action of P_r or P_s was no longer effective as more crystals developed and increased in size, exposing more surface to the free monomers. In addition, the crystals with inhibitor attached could simply redissolve. Without careful temperature and concentration control of the crystallization process, the just detached P_r or P_s would no longer have inhibited crystal growth.

What the experiments do show is how much expertise is required to know how to generate an e.e. But, instead of revealing that e.e.s could have arisen for AAs via natural processes, examples like these illustrate the opposite: intelligent organization was necessary.

We will conclude part 1 of this series with the main commonly cited, but absurd or irrelevant, claims of an $e.e._L$ produced naturally on various minerals.

Selective adsorption on various minerals

Kaolinite mineral clay

Claims of stereoselective adsorption of AAs on clay mineral kaolinite ($Al_2Si_2O_5(OH)_4$) and of stereoselective polymerization of aspartic acid catalyzed by kaolinite have been discredited following re-examination by various researchers employing better analytical methods.[17,32,33]

Montmorillonite clay

L-leucine, L-aspartate, and D-glucose were claimed to bind in a stereospecific manner onto the montmorillonite clay ($(Na,Ca)_{0.33}(Al,Mg)_2(Si_4O_{10})(OH)_2 \cdot nH_2O$), which is the major component of the adsorbent swelling clay bentonite. The non-biological enantiomers D-leucine, D-asparatate, and L-glucose allegedly did not exhibit any selective adsorption.[34] However, Youatt and Brown demonstrated shortly afterwards that this was a misinterpretation of the experimental data.[35]

The two examples above illustrate a recurring principle in the OoL literature. A disconcertingly large number of publications alleging a break-through in the origin or amplification of homochirality pass peer review in leading journals like *Science* and *Nature*, but other teams can't replicate the claims. Many examples of this can be found in a review paper by evolutionist Standard University professor Bonner.[17]

Bonner summarizes all attempts to produce an enantiomeric excess with clay minerals with the sobering words:

> "Thus there is no experimental evidence whatsoever to date supporting any stereoselective effects on prochiral or racemic substrates attributable to clay minerals."[17]

The initial hype fades and is replaced with a new claim, but it seems that a feeling has developed that steady progress is

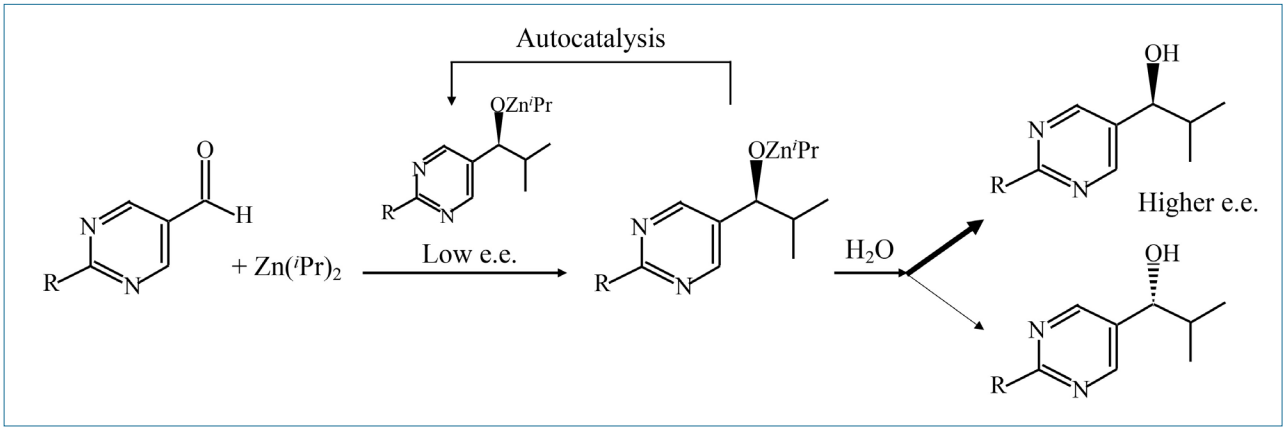

Figure 3. Autocatalytic amplification of enantiomeric excess in the Soai alkylation of pyrimidyl aldehydes. Diagram based on insights from refs 25 and 27.

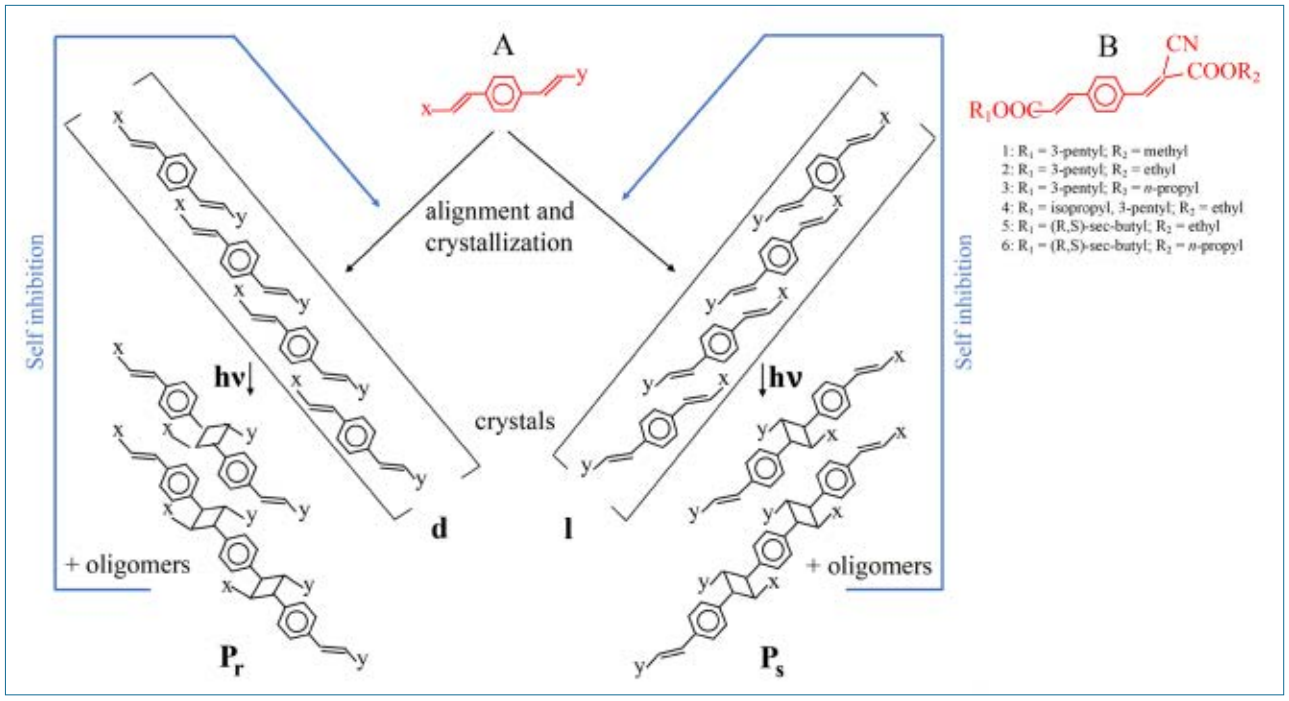

Figure 4. A. Feedback inhibition of enantiomer crystals during production of chiral cyclobutane derivatives from non-chiral dienes. B. Ester substituents used in ref. 29.

being made in explaining the original of pure L-AAs. Heavily marketed sensationalized claims are not easily forgotten, but reports of disproof do not receive the same fanfare.

I'll next mention some examples of small levels of e.e. obtained in carefully designed surfaces under special laboratory conditions. To evaluate their relevance for OoL purposes, one should always examine the concentrations of AA used, pressures, and avoidance of contaminants. But most importantly, in nature, both mirror-image surfaces would form in the same proportions, cancelling out any net e.e.

$CaCO_3$ (calcite) crystal

Calcite ($CaCO_3$) and other minerals form mirror-image surfaces on the same crystal. Hazen and co-workers immersed a rhombohedral calcite crystal in an aqueous solution of racemic AAs (aspartic acid or alanine) and found that crystal faces of a particular handedness selectively adsorbed the D- or L-AA enantiomer.[36] However, as anticipated the mirror-image crystal face selectively adsorbed the opposite AA.[37] Therefore, under natural conditions, no net e.e. could result. Furthermore, this effect was not observed with other amino acids tested, such as valine and lysine.[36]

Chemists have also succeeded in producing other kinds of crystals having chiral faces with which some enantioselectivity was obtained for some heterogeneous reactions and photodimerizations, both of which are however irrelevant for OoL purposes.[38–40]

Chiral minerals such as quartz

Some chiral minerals such as quartz can exist as in dextro- and levorotatory enantiomorphs. Preferential adsorption of one AA enantiomer on right-, (+)-, or left-handed, (−)-, crystal forms of quartz was first proposed as possibly producing chiral molecules in the 1930s.[41]

Bonner *et al.* were only able to generate low e.e.s ~20% for D-alanine adsorbed on d-quartz. This required using non-aqueous solvents irrelevant for OoL purposes with moisture carefully excluded.[36,42–46]

Extensive examination has shown that D- and L-quartz are present in equal amounts worldwide, and so no net selectivity would result.[17,47] In 1962, Palache *et al.* collected 17,738 samples worldwide and found 1.4% excess of (−)-quartz (50.7%) over (+)-quartz (49.3%) (i.e. a 1.4% excess).[48] This is within the expected statistical variability expected from a sample size so much smaller than the population of all suitable quartz crystals. The variance of a binomial distribution is given by

$$\sigma^2 = np(1-p) \qquad (2),$$

where n is the sample size (17,738) and $p = 0.5$ is the probability of obtaining a quartz of either form. This leads to a standard deviation of $\sigma = 66.6$. About half of the sample (8,869) should be found as each form of quartz and 2σ correspond to 133. Therefore, about 95% of random samples

of this size would have one quartz form in an amount of 8,849 ± 133, which is ±1.5% from the expected mean (±100 × 133/8,849). The reported 1.4% excess of (−)-quartz lies within the range of random sampling.

In a later, larger study Frondel examined 27,053 samples and found 50.17% (+)- and 49.87% (−)-quartz, which is also within the range of random sampling. But this time, a tiny excess of the *opposite* form of quartz was found over that found in the Palache study.[49]

Glycine crystals doped with D-amino acids

The faces of glycine crystals have been used to separate AA enantiomers at an air/water interface.[17,28,50,51] Plate-like crystals of glycine tend to float at the air/water interface, exposing the (010) or ($0\bar{1}0$) face to air in equal proportions.[28] Experiments with several chiral α-AAs revealed that (*R*) enantiomers are preferentially adsorbed at the (010) crystal face.[28,36]

Consequently, when the crystals were produced together with small amounts of pure D-leucine, D-phenylalanine, or D-α-aminooctanoic acid, the hydrophobic side chains caused the floating crystals to always expose the ($0\bar{1}0$) face to the air side. Since the other face is now exposed to the water phase, non-hydrophobic AAs also present would only attach there. Experiments showed that crystals grown in the presence of equal amounts hydrophobic D-leucine mixed with L-glutamic acid, L-methionine, L-alanine, or L-serine, continued to have platelets with the ($0\bar{1}0$) faces directed to the air. HPLC analysis showed that the aforementioned L-AAs occluded within the crystals were found in high e.e.

Critique of these studies

These kinds of experiments could find application for manufacturing purposes, for example by designing two-dimensional crystallites optimized to form chiral monolayers.[52–55] But there are many reasons why such a process could not have arisen naturally:

- The production of pure glycine crystals and then location to an air/water interface is not plausible.
- The amount of enantioenrichment which could have been created in the liquid phase would have been negligible, and the glycine crystals could redissolve and liberate the contained AAs. Consequently, an OoL scenario must involve the air phase only.
- Enantioenrichment in crystals on faces aimed towards air would serve no purpose. To form peptides, they would have to redissolve in water, where racemization would occur along with contamination with D-AAs. Note that any e.e. in the air phase could only have arisen from impoverishment in the solution phase, and so redissolving would undo the enantiomer separation.
- The process required the presence of pure D-AAs, which would have been devastating if proteins were to have arisen using only L-AAs.
- The minority of suitable hydrophobic D-AAs would have competed with other D-AAs at the same crystal phase, hindering orientation to the air side.
- The proportion of hydrophobic D-AA to L-AA would need to be close to 1:1 to produce a relevant $e.e._L$.

Crystal conglomerates using amino acids with large alkyl groups

Weissbuch *et al.* studied some racemic *α*-AA having the structure $RHC(NH_3^+)CO_2^-$ which form monolayers on water and on glycine aqueous solutions.[53] Heterochiral crystals were synthesized by using $R = C_nH_{2n}+_1$, n = 10, 12, 16 and homochiral crystals by using $R = C_nH_{2n}+_1CONH(CH_2)_4$, n = 11, 17, 21. In the latter case, adjacent hydrocarbon chains are held together due to N–H•••O=C hydrogen bonds between amide groups.

The long chains formed separate 2-dimensional islands having single (*R*) or (*S*) enantiomers. However, the individual crystalline domains are very small. For the long-chain amides, the lengths of a single island were about 170, 500, and 300 Å along the (0,1), (1,0), and ($1,\bar{1}$) lattice plane directions. Conglomerates of domains are formed; i.e. mixed enantiomorphous crystals. The overall amounts of (*R*) and (*S*) domains formed are identical. Thus, as typical of enantiomeric amplification examples, the enrichment refers to a tiny region which is not naturally separate from the mirror-image enantiomer.

Critique of these studies

- The AAs were first dissolved in unique laboratory solvents, chloroform/trifluoroacetic acid (v/v 98:2), then carefully spread on a concentrated glycine aqueous solution at 8°C. Compression of the monolayer using a Langmuir trough was accompanied by further cooling to 5°C. These are not relevant conditions for a putative prebiotic earth.
- Little evidence for any crystal formation was found in the absence of concentrated glycine.
- Even when using glycine in water, no islands were found for chains as short as $R = C_6$ and C_8, sizes relevant to the sidechains of biological AAs. In other words, the molecules used cannot have contributed to a natural origin of biological AAs.
- The formed conglomerates are an intimate mixture of (*R*) and (*S*) regions. No natural full separation of enantiomers was achieved.

Using a Langmuir trough

Racemic mixtures of amphiphiles, such as fatty acids, alcohols, amides, and amino acids, can sometimes be engineered to separate into left- and right-handed molecule islands at the air–water interface of a Langmuir trough.[56] The enantiomers separate into crystalline islands of opposite handedness. The various chemical structures organized are located at the air–liquid interface and the solution phase due to interaction with the monolayer.[54]

Griffith and Vaida claimed that similar environments could have existed on the ancient surfaces of lakes, oceans, and atmospheric aerosols. This is, at best, very wishful and unsubstantiated thinking. In a key paper, they describe how the amino acid leucine was first chemically activated by converting the end carboxyl group to an ethyl ester.[57] In addition, for the condensation to proceed, coordination to Cu^{2+} (copper(II) chloride) was necessary and the final solution was sonicated until a transparent solution resulted.[57] Finally, an unrealistically high externally applied pressure of 15 mN⁄m was applied to force the orientation of the molecules.

In natural conditions, a wide variety of chemicals could also mix with the amphiphiles. Solutes (including unnatural amino acids) can prevent or retard formation of monolayer crystallites and also dissolve them once formed.[54]

Critique of these studies

- Any substance related to an AA first had to be chemically modified. There would have been no steady supply of feedstock such as esterized AAs,
- Coordination of AAs with a high concentration of Cu^{2+} would have accelerated racemization, whereas the goal was to find a natural way to produce only L-AAs.[58]
- Careful experimental control by the experimenters was necessary, using a highly concentrated solution of pure substances at a high pressure, which was carefully increased in a way and rate which minimized turbulence.

Concluding comments

Several mechanisms to explain the origin of an enantiomeric excess or enrichment of one enantiomer have been proposed over the years. These were usually marketed with great fanfare and shamelessly oversold. The mechanisms discussed here were selected as being those clearly irrelevant for abiogenesis purposes. They continue to be referenced in the current OoL literature but rarely is the fact emphasized that they are no longer being actively researched nor that they were unfruitful.

In the next parts to this series, we will focus on the ongoing proposals which have not yet been demonstrated to be just as irrelevant to explain the origin of enantiomerically pure biochemicals.

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Enantiomeric amplification of L amino acids: part 2—chirality induced by D-sugars

Royal Truman

D-enantiomer sugars have been shown in some reports to mediate formation of an enantiomer excess (e.e.) of some biological amino acids (AAs) via the Strecker synthesis. The claim that this might explain how proteins based on only L-AAs could have arisen naturally is shown to be unrealistic. Some sugars increased the e.e.$_L$ of the AAs produced, whereas others caused the opposite effect, cancelling each other's effect. The required presence of concentrated, pure aminonitriles together with pure D-sugars is extremely implausible in a putative prebiotic Earth. So is the rapid change from a pH of ~11 to a to highly acidic aqueous solution required to hydrolyze the intermediates. Based on some experiments using a phenylalanine precursor which led to L-phenylalanine, one paper claimed that an unnatural sugar like D-lyxose may have played an important role in the origin of life (OoL). However, a later paper showed that the analogous alanine precursor in the presence of D-lyxose led instead to the unnatural D-alanine. The measured e.e.s were merely short-term laboratory artifacts arising from the high proportion of sugar used, which temporarily sequestered one AA precursor enantiomer. This was soon released and would soon lead to a racemic mixture of AAs.

We continue here with part 2 of a series of papers that claim an enantiomer excess (e.e.) of L amino acids (AAs) could arise naturally once an initial excess has somehow become available.

One approach to forming an e.e.$_L$ involves reactions mediated by chiral catalysts or chiral auxiliaries. Key experiments reported in 2017 documented the effect of chiral aldopentose sugars to mediate enantioenrichment of AA precursors in the Strecker synthesis (see pathway B in figure 1 and the results shown in table 1).[1] This differs from most of the experiments analyzed in this series, which amplify a small e.e. of an already existing AA. In this paper the pre-existing excess was present in sugars.

Adding D-pentoses to the Strecker reaction

The authors claimed they have contributed to solving the riddle of the origin of enantioselectivity of both sugars and AAs, claiming that

> "This work adds to growing evidence for synergy in the etiology of the single chirality of the two most important classes of biological molecules, the sugars that make up DNA and RNA and the amino acids that form proteins."[1]

And also add:

> "… this kinetic resolution may be configured so that either the amino acid resolves the sugar or, conversely, so that the sugar resolves the amino acid."[1]

Pure aminonitriles (compound III in figure 1) were used to synthesize aminoamides (IV) under very basic conditions (pH ≈ 11) in the presence of various D- or L-sugars. The e.e. of the aminoamide intermediates in the Strecker reaction typically increased for a few days under the reaction conditions before plateauing to a maximum. NMR spectroscopy indicated that several covalently bound aminonitrile-sugar species were present, responsible in some manner for the resulting e.e.[1]

The results are summarized in table 1.

The enantioenrichment effect on AAs produced by D- and L-sugars was confirmed to be symmetric within measurement error (see table 2).

The e.e. depended strongly on the fraction of pure sugar present as catalyst. In this study, the authors reported an e.e. drop from 43% to 9% when the molar proportion of D-ribose:α-aminonitrile was decreased from 1:1 to 0.1:1 (see table 3).

The data from table 3 was plotted to obtain a simple polynomial curve to help visualize the enantioselectivity effect (see figure 2). The empirical equation clarifies that decreasing to more plausible values such as 0.01 relative equivalents, and using less than 100% pure D-ribose, would produce an e.e. <1%.

It will be important to keep in mind for the next section that the data in table 1 and table 2 refer to the amide intermediates before hydrolyses were performed under acidic conditions to obtain the AA (V). Without this hydrolysis step, none of the AA was obtained and the hydrolysis step IV → V did not affect the chirality.[3] It must be emphasized that the data in these tables show that the biologically 'correct' D-ribose and D-deoxyribose produced the biologically 'wrong' D-AA precursors IV, whereas D-lyxose produced the desired L- precursor with high e.e.$_L$!

This led the authors to conclude:

> "Our results suggest a key role for other prebiotically common D-pentoses such as D-lyxose in mediating the emergence of L-amino acid homochirality."[1]

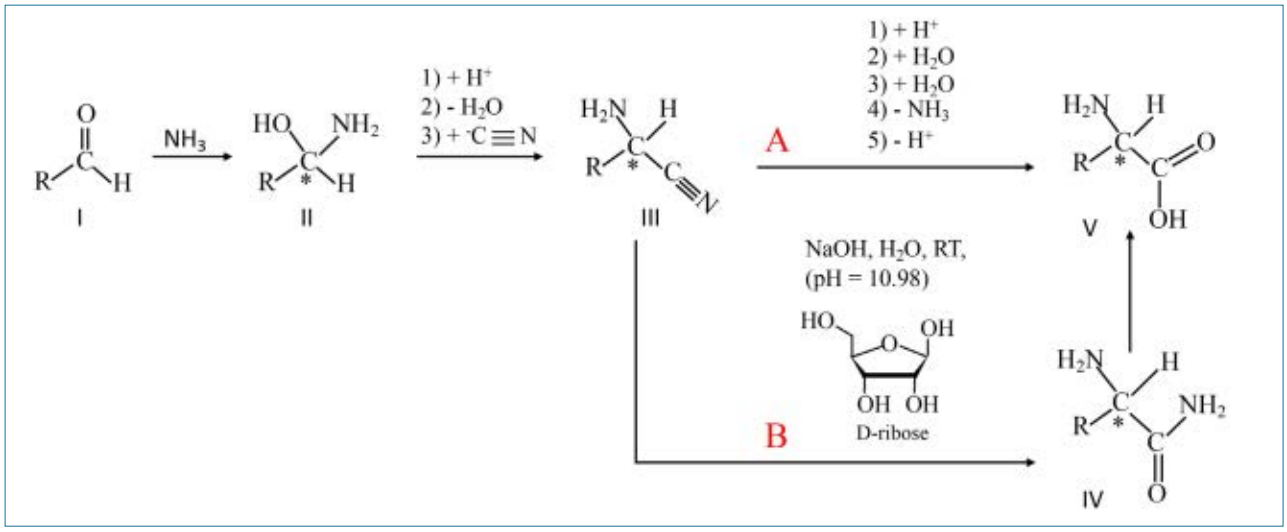

Figure 1. Enantioselective synthesis of amino acid precursors mediated by chiral sugars as part of a Strecker synthesis[1,2]

Table 1. Enantiomeric enrichment (e.e.) in % of aminoamides formed from aminonitriles (molecules IV and III, respectively, in figure 1) in the presence of D-sugars.[a] Data from ref. 1. Ala = alanine, Phe = phenylalanine, Trp = tryptophan.[1]

Sugar	Ala-IV	Phe-IV	Trp-IV
D-ribose	65 (D)	70 (D)	33 (D)
D-lyxose	83 (L)	83 (L)	59 (L)
D-xylose	45 (D)	35 (L)	11 (D)
D-arabinose	58 (L)	48 (L)	38 (L)
D-deoxyribose	29 (D)	32 (D)	33 (D)
Average effect[b]: ee_L	*0.4*	*-1.2*	*4*
D-ribose + D-lyxose	45 (L)	14 (L)	18 (L)
D-ribose + D-lyxose + D-xylose + D-arabinose	47 (L)	18 (L)	20 (L)

[a] Reaction conditions: 0.25 M α-aminonitrile (III in figure 1) mixed with 0.50 M sugar in H_2O with 0.25 M NaOH at 22–24°C. Ala and Phe precursors were reacted for 7 days, and Trp precursor for 5 days.
[b] Average calculated using negative values for ee_D and positive values for ee_L.

The importance of D-lyxose was further emphasized in this 2017 paper, with the authors stating that derivatives of this sugar had been identified on meteorite samples and had exhibited significant $e.e._D$.[4]

They emphasized this by pointing out that when the conversion of III → IV was mediated by a mixture of equal amounts of D-ribose and D-lyxose, or equal mixtures of the four D-pentoses, an $e.e._L$ of IV resulted, see table 1, last two rows. We will revisit this key result in the next section when reviewing longer-term experiments reported in 2021using racemic alanine aminonitrile (III) instead of phenylalanine aminonitrile. The researchers chose not to perform the analogous experiments done in 2017 using the same mixed sugars.

Despite the contradictory effects obtained when catalyzing with different sugars, the reader is assured that

> "Prebiotically plausible mixtures of natural D-sugars lead to enantioenrichment of natural L-amino acid precursors."[1]

In the next section I will present a paper published four years later, having Blackmond also as the lead author, which turns these results upside down, but I'd like to first consider the 2017 paper on its own merits.

Critique of these studies

There are several objections to the conclusions reported in 2017.[1] This paper illustrates some principles pointed out in 2022 in this journal on how bias affects which experiments to perform and how to report the results.[5]

Ideal pure starting materials were used

The chemicals used to produce sugars and AAs would have created an overwhelmingly messy mixture of materials instead of the necessary pure monomers required by DNA, RNA and proteins. Typical of these kinds of OoL experiments, the true chemical outcomes under conditions not optimized to produce the desired outcomes were not predicted. Only the desirable molecules, such as aminonitriles, were placed in clean reaction vessels in ideal proportions, protected from contaminants and interferents that lead to cross- and competing reactions.

D- and L-enantioselectivities cancelled

In OoL publications and discussions, one frequently encounters the claim that D-sugars catalyze production of L-amino acids under natural conditions. But examination of the data shows this claim is false. The data in table 2 confirmed the chemical expectation that the effects of D- and L-sugars in the enantioenrichment of aminoamides IV is symmetrical and counteracted each other for the same AA precursor.

The data in table 1 purports to show a net enhancement of L-AAs by D-sugars, especially for tryptophan. But some D-sugars increase, and others decrease the enantioenrichment of the aminoamides produced, tending to cancel out. I show in table 1 that the average effect, beginning with single pure D-sugars, ranges from e.e.$_L$ –1.2% to 4%, and we can see that the miniscule *larger amount of L formed is due to only D-lyxose*, a very rare sugar metabolized by some bacteria which would have been naturally present in only negligible concentration.

Deliberate experiments to emphasize catalysis using D-lyxose

Diverse sugars would differ in their effectiveness as catalysts, and so more experiments are needed than merely using an average value. It is unlikely that a considerable amount of the same D-sugar could have been present in some aqueous environment by chance; a mixture of D-sugars in various proportions would be more plausible. Which pure D-sugars should be combined for these experiments? D-ribose and D-deoxyribose (used to construct RNA and DNA) are obvious choices since the motivation of this work is to find a plausible synergistic way to naturally produce L-AAs. But table 1 shows that both these D-sugars led to AA precursors with the biologically 'wrong' (i.e. D) form. Performing and reporting the results of such experiments would discredit the authors' apparent purpose of this research project. A more objective research team would have conducted these obvious experiments anyway, which would have falsified the theory of protein, RNA and DNA enantiomeric synergies.

The authors astutely included the exceptional D-lyxose in all the mixed sugar studies since it produced the desired strong L-AA enhancement in the unique case of phenylalanine. However, the most relevant sugar D-deoxyribose, the key component of DNA, was excluded from the mixture studies. Consequently, the authors were thereby able to report a net selectivity of L-AA precursors in their results. Those with a more biologically relevant objective would surely have also reported the results from experiments using mixtures of the two most relevant D-sugars instead of focusing on the biologically irrelevant D-lyxose.

The authors justify using D-lyxose in these studies by stating:

> "… enantioenriched derivatives of the biologically rare lyxose were found in similar abundance to derivatives of ribose on two separate meteorites."[1]

Table 2. Enantiomeric enrichment (e.e.) of aminoamides formed from aminonitriles (see molecules III and IV in figure 1) in the presence of D- and L-sugars is symmetrical within experimental error.[a] Data from ref. 1.

Sugar	Phe-IV e.e.	Sugar	Phe-IV e.e.
L-ribose	69 (L)	D-ribose	-70 (D)
L-lyxose	-81 (D)	D-lyxose	83 (L)
L-xylose	31 (L)	D-xylose	-35 (D)
L-arabinose	-43 (D)	D-arabinose	48 (L)
Average[b]:	*-6.0*		*6.5*

[a] Reaction conditions: 0.25 M *α*-aminonitrile (III in figure 1) mixed with 0.50 M sugar in H_2O with 0.25 M NaOH at 22–24°C; 7 days.
[b] Average calculated using negative values for ee$_D$ and positive values for ee$_L$.

Table 3. Effect of D-ribose concentration on enantiomeric enrichment (e.e.$_D$) for phenylalanine aminoamide (Phe-IV).[a] Data from ref. 1.

[D-ribose] (M)	D-ribose equivalents	Phe-IV e.e. (%)
0.025	0.1	9 (D)
0.050	0.2	14 (D)
0.10	0.4	23 (D)
0.25	1	43 (D)
0.5	2	43 (D)
1.0	4	41 (D)
2.0	8	42 (D)

[a] Reaction conditions: Phe-III at various concentrations with 0.25 M NaOH in H_2O at 22–24°C, 1 day. The enantiomeric excess (e.e.) refers to molecule IV in figure 1.

Note the word *derivatives* in the above quote. Lyxose itself was not delivered to Earth but had to be chemically extracted in a laboratory under vigorous hydrolysis conditions. They also did not mention that Cooper and Rios, who authored the paper they quoted, reported finding a possible trace amount of D-lyxonic acid in the soil in the immediate area where the Murchison sample was found, implying this e.e. may have originated from terrestrial bacteria.[4] This is quite reasonable, considering that most chiral meteoritic compounds have been found to be racemic mixtures.[6]

But what Cooper and Rios reported after chemical processing of material dissolved out of the two meteorite samples was *D-lyxonic acid*. No justification was provided for using *D-lyxose* instead in the experiments as the sugar catalyst, nor was this substitution even mentioned.

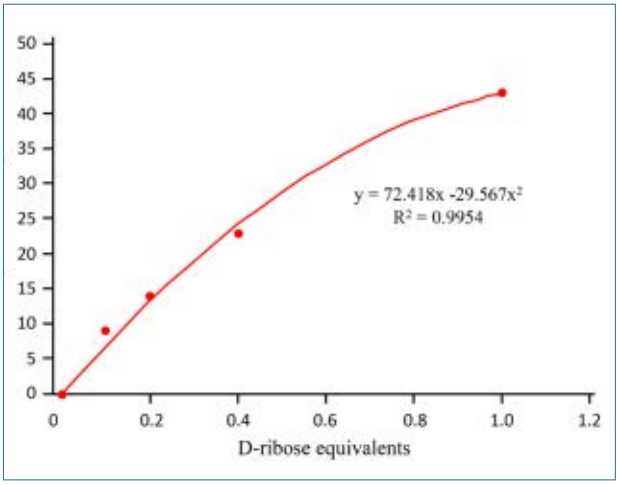

Figure 2. Effect of D-ribose concentration on e.e.$_D$ (%) of phenylalanine aminoamide (Phe-IV) produced. The data from table 3 was fitted with a second-degree empirical polynomial curve.[1]

It must be emphasized again that the sugars found in meteorites are bound in large complex substances which only existed as sugars after being freed using vigorous chemical liberation conditions. This makes it unrealistic to accumulate concentrated sugars from meteorites under natural conditions. One must avoid the error of thinking that perhaps exposure to higher temperatures and millions of years could have eventually freed the bound compounds. Under such circumstances the AAs and sugars would have been lost e.e. through racemization.[6–9]

Multiple synthetic steps under incompatible conditions

In the reaction overview shown in figure 1, the intended products were AAs. Conversion of aminonitrile III → IV was carried out at a pH ≈ 11, but hydrolysis of IV to form V did not occur under the reaction conditions for the phenylalanine pathway:

> "… further hydrolysis to the amino acid was not observed and was found to require more forcing conditions."[2]

Amides can be hydrolyzed in either acidic or basic conditions. In laboratories and chemical manufacturing, alkaline hydrolysis involves heating the amide with hot aqueous sodium or potassium hydroxide, but these conditions would rapidly racemize any biologically relevant AA. Therefore, acidic conditions would make more sense, using sulfuric or hydrochloric acid, and temperatures of about 100°C for several hours.[10]

Unlike these highly skilled chemists, nature would not foresee that the chiral centre must not be damaged by removing the proton at the α-carbon under the highly alkaline conditions of the preceding reaction step. Over hundreds or thousands of years the AAs produced would have racemized V. Alternatively, it is unreasonable to demand chance to transfer the aminoamide IV from an environment with pH near 11 to a very acidic one at just the right time.

To reiterate, the reaction steps shown in figure 1 were not *one-pot reactions*. Each intermediate was synthesized under a separate set of ideal conditions and reagents. Typical of OoL experiments, the intermediates were purified, then isolated, and then new laboratory setups used with different reagents and conditions for the next step. Here, as in almost all such studies, pure intermediates (like aminonitriles III) were simply purchased, since organic chemists know that beginning with aldehydes like I mixed together in water with all the other reagents needed such as NH_3, HCl, NaOH, KCN and sugars would produce amino acids V in at best trace amounts mixed with a complex mixture of other chemicals.

Therefore, the researchers introduced pure D-sugars precisely at the beginning of the key reaction of aminonitriles III shown in figure 1, thus avoiding the complex and poly-functional mixtures resulting from exposure of these sugars to the other key reactants I, II, and V.

Unrealistic concentrations and stoichiometries are used

For the key step shown in figure 1, 0.25 M of an aminonitrile III was mixed with 0.50 M D-sugar in water. Aminoamide products IV were produced in 9−29% isolated yield.[1] This was accomplished with the help of 0.25 M NaOH at 22−24 °C. Ala-III and Phe-III were reacted for 7 days and Trp-III for 5 days.[1]

However, these are massively unrealistically high concentrations of III plus D-sugar under natural conditions, which would have had to be present concurrently during an appropriate time interval. It is legitimate to use optimized concentrations and ratios for research convenience, but one should then extrapolate to natural conditions. Even assuming the most extremely optimistic coincidence of conditions, nature does not provide hermetical constraining volumes with just the right reagents in ideal proportions along with a continuous mixing mechanism (as with the laboratory's magnetic stirrer).

To illustrate, one could place a few drops of concentrated III and D-sugar in close proximity in a container the size of an Olympic swimming pool, and then determine a week later how much IV is found throughout the entire volume. Given the statistical impossibility of finding twice as much D-sugar as III in a nearby volume, and the relative ease of hydrolysis of III under fluctuating temperatures and high concentration of bases, no detectable e.e.$_L$ of product IV would be likely to form naturally.

Long times would be necessary

A pH ≈ 11 (required to produce aminonitriles IV) would racemize the target L-amino acids V. Perhaps a lower pH could be used to form IV instead. The authors tested a stoichiometry of 2:1 D-ribose:III with deionized water (pH = 7) and also 0.0001 M NaOH (effective pH = 10), obtaining

e.e.$_L$ values of only 35% and 36% respectively (see table 4 in ref. 1). This is half the e.e.$_L$ of 70% we saw in table 2 even though the researchers had increased the reaction time from 7 to 35 days. Greater separation through diffusion would result (recall the example of using a swimming pool above), resulting in reactant concentrations below threshold levels within minutes. This would have led to no catalytic effect from the D-sugar.

We could continue to extrapolate into more plausible conditions by also evaluating the effect of lowering the proportion of D-sugar:III, based on the results from table 3 and figure 2. Recall, however, that these are trapped in a close container and mixed with a magnetic stirrer, rapidly forcing the reagents into close contact. The rational conclusion is that the e.e.$_L$ reported is only an artifact of the carefully planned experiments. Any L-AA V formed from IV would do so exceedingly slowly and would racemize in water. Not only would the theoretical e.e. generated be negligible at any location, but it would also be present in very low concentration at any time.

Some systematic experiments monitoring aminoamide e.e. values for longer than merely a few days would have been helpful to extrapolate to prebiotic natural conditions and to demonstrate the impossibility of the proposed mechanisms. One would expect the aminoamides to racemize, especially in the presence of a strong base. From table 4 of the paper, we observe that the e.e.$_D$ for Phe-precursor decreased from 46% to 36% when, instead of pure water as solvent, 0.00010 M NaOH was used at 37°C after 35 days.[1] Thus, presumably an initial e.e. produced in some manner would racemize over time (weeks), especially after thousands or millions of years.

Even though the aminonitrile III disappeared in under 4 hours, the e.e. of Phe-IV increased from a racemic mixture at the outset of the reaction and continued to rise for nearly 1 week, (see figure 3).

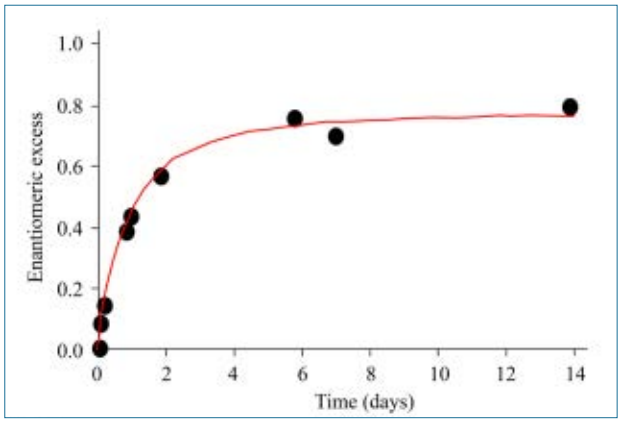

Figure 3. Increase in enantiomeric excess over time for the conversion of Phe-III (see reaction in figure 1) to form Phe-IV catalyzed by D-ribose. Reaction conditions: 0.25 M aminonitrile III with 0.50 M D-ribose in H_2O with 0.25 M NaOH at 22–24°C.[1]

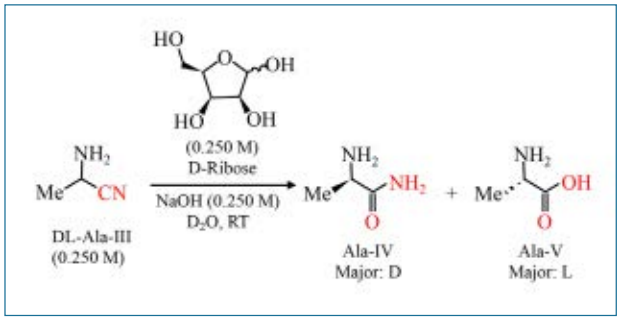

Figure 4. Sugar mediated reaction of Ala-III to Ala-IV and Ala-V (after a figure in the Suppl. Material of ref. 2). Conditions: DL-Ala-III (0.250 mmol), D-ribose (0.250 mmol), 0.50 M sodium benzoate in D_2O as internal standard and 2.50 M NaOH in D_2O. D_2O was added to the volumetric flask to produce the final solution.[2]

Enantiomeric excess for alanine in the presence of D-ribose

The focus of the 2017 paper was on the synthetic pathway for phenylalanine.[1] In a later paper published in 2021, the alanine pathway was examined with results inimical to the conclusions of the earlier paper.[2] We see that now to obtain an e.e.$_L$ for alanine, the presence of D-lyxose is the last thing the OoL researchers would want, since it catalyzed formation of D-alanine instead!

The Ala aminonitrile III (instead of Phe, as before) now produced L-V in the presence of D-ribose, see figure 4.[2] The difference was that Ala-IV hydrolyzed to Ala-V (whereas Phe-IV had not) and the sugar enhancer changed the chirality during hydrolysis. Recall that in the 2017 report, hydrolysis to form Phe-IV required a separate step, using strongly acidic conditions which did not change the chirality.

Figure 5 shows the development of e.e.$_D$ for Ala-IV and Ala-V over time. Ala-IV was nearly racemic initially but eventually formed a 13% e.e.$_D$, whereas Ala-V, initially c. 50% e.e.$_L$, rose to 68% e.e.$_L$.

To recap, table 1 showed, for the 2017 study, that racemic Phe-III in the presence of *D-ribose* resulted primarily in D-Phe but in primarily the biological L-Phe in the presence of *D-lyxose*.

The 2021 study produced the opposite results. Racemic Ala-III in the presence of *D-ribose* resulted primarily in L-Ala and primarily D-Ala in the presence of *D-lyxose*. Embarrassingly, D-lyxose was revealed to be detrimental to producing L-AAs, contradicting the break-through discoveries in the 2017 paper.

The chemically simpler Ala or its derivatives would be much easier to form naturally than Phe and is/are found in much higher proportion in proteins. Since rac-Ala-III in the presence of D-lyxose would inevitably lead to D-Ala (the 'wrong' AA) without any change in reaction conditions, an OoL researcher might wish to switch strategy and now downplay the existence of this sugar. Unfortunately, this

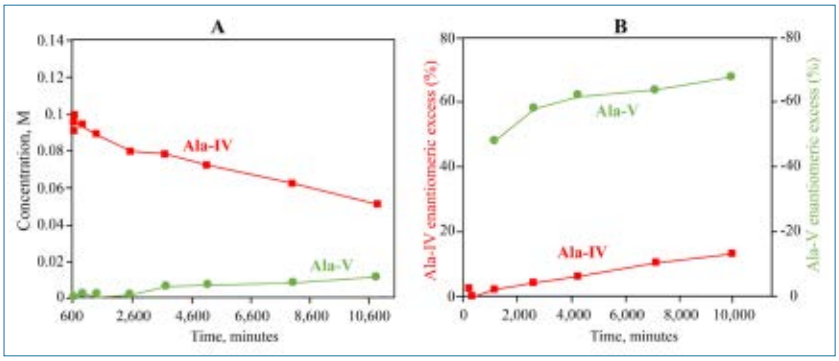

Figure 5. Monitoring of the reaction in figure 1 carried out with 0.125 M racemic Ala-III (the aminonitrile), 0.125 M D-ribose, and 0.01 M NaOH in D_2O at ambient temperature. pH at the outset of the reaction was 10.98. (A) Concentration of Ala-IV (the amide intermediate, red squares) and Ala-V (the final amino acid, green circles). (B) Loss of $e.e._L$ Ala-IV (red squares) and Ala-V (green circles) over time. Positive e.e. values refer to the D enantiomer.[2]

would then eliminate the most effective sugar known to obtain L-Phe from racemic Phe-III.

In the 2017 paper, mixed sugars which always contained D-lyxose with Ph-III were heralded enthusiastically as a means for obtaining L-Phe, but the analogous experiments using the same mixtures with Ala-III were not carried out later, perhaps once the anticipated results became known. This is an example of how the choice of research to be conducted predetermined what readers learned, and misled them into thinking that the bulk of the evidence supported evolution.[5]

Perhaps the most important fact about these experiments is that the e.e. found is only a temporary effect. The kinetic and NMR analysis demonstrated that when an excess of L enantiomer was obtained, much of the potential D-AA remained sequestered temporarily and would be automatically produced later.

Figure 6 shows how the proportion of D-Ribose and NaOH strongly affected how much L-Ala-V formed. The green points represent excess of L, and the right axis represents $-e.e._D$ values. One notes how, within mere days, the initial $e.e._L$ began to decrease and would soon lead to a racemic Ala mixture.

Clearly the e.e. effects reported were merely a laboratory artifact obtained under unnatural conditions, caused primarily by exposure to extremely high proportions of the D-sugar present.

The data shown in figure 6 reveals that a researcher could have obtained high or low e.e. values and increasing or decreasing trends with time depending on the exact conditions and duration used. Unusual non-equilibrium short-term effects can be obtained by selecting suitable parameters. But naturalist models require deep time. The relevant consideration is what would result after thousands or millions of years with no deliberate guidance. Under the already implausible conditions selected for the data found in figure 6, waiting a few months would have revealed no e.e. present at all!

Additional critical observations

Where would the high concentration of a sugar such as D-ribose have come from? The scenario favoured by the OoL community involves polymerization of formaldehyde (the formose reaction), against which chemistry professor Shapiro has levelled devastating chemical objections.[11] In the words of Weiss *et al.*:[12]

> "The formose product can be regarded as a carbohydrate analog of petroleum, in that it contains so many carbohydrates of varying molecular weight and isomeric structure."

Formaldehyde has little tendency to react with itself to form carbon–carbon bonds and instead much of the formaldehyde is used by other chemical processes such as the Cannizzaro reaction.[13] In fact, formaldehyde reacts much more easily with many other substances used in various prebiotic proposals, including ammonia, amines, amides, imides, aminonitriles, urethanes, and urea.[12]

Reid and Orgel were not able to produce any sugar-like substances from formaldehyde unless the concentration was at least 0.5 M, a concentration far, far higher than could arise naturally.[14] Miller and Orgel have also stated that it would be problematic for a high enough concentration of formaldehyde to have existed on a primitive Earth to produce even *trace* amounts of D-ribose.[15] Once some sugar has formed via the formose reaction, further reactions would have to be quickly stopped (e.g. within about 10–13 min) to prevent decomposition.[14,16]

OoL researchers Reid and Orgel therefore have concluded:[14]

> "We do not believe that the formose reaction as we and others have carried it out is a plausible model for the prebiotic accumulation of sugars."

And Shapiro adds:[12]

> "Little has happened in the decades since that report to alter the above judgement."

Another issue is that D-ribose isomerizes easily. Tewari and Goldberg reported that an initial sample of D-ribose formed a mixture of 75% D-arabinose, 6% D-ribulose, and that only 19% D-ribose remained within a few weeks at 25°C and pH 7.[17]

Final comments

The experiments discussed above were not conducted under a consistent set of conditions to form D-ribose, D-deoxyribose, and the 19 L biological amino acids. Some D-sugars led to an e.e. of L-AAs, whereas other sugars

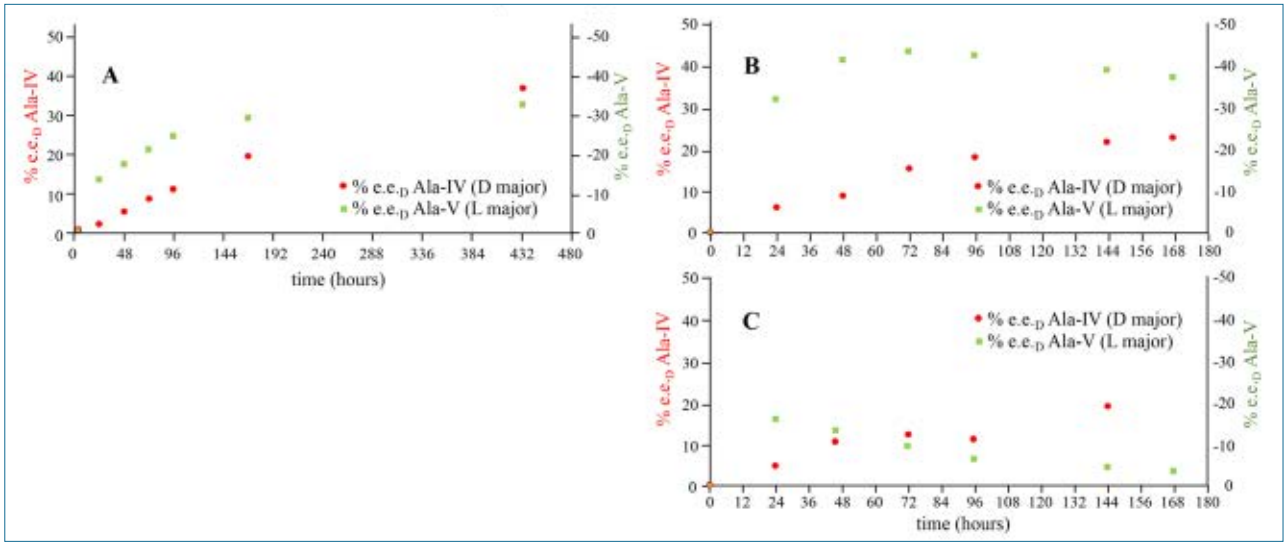

Figure 6. Change in enantiomeric excess of Ala-IV and Ala-V over time under different proportions of D-Ribose and NaOH. Ref. 2, Supplementary Materials.
(A) DL-Ala-IV HCl (0.250 M), D-Ribose (0.500 M), NaOH (0.500 M). Figure S6 in Suppl. Materials.
(B) DL-Ala-IV HCl (0.250 M), D-Ribose (0.260 M), NaOH (0.260 M). In carbonate buffer (1.000 M) to keep pH constant. Obtained from figure S10 in the Supplementary Materials.
(C) DL-Ala-IV HCl (0.250 M), D-Ribose (0.250 M), NaOH (0.500 M). 50 µmol of NaOH were added every 24 hours to keep constant the pH of the reaction mixture. From figure S8 in the Supplementary Materials.

enhanced the opposite, and the effects were not inconsistent for the various AAs. Without the guidance of the researchers, over time racemic mixtures of AAs would have formed.

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Enantiomeric amplification of L amino acids: part 3—using chiral impurities

Royal Truman and Chris Basel

Several studies attempting to provide a natural method for L-amino acid (AA) amplification have been critically examined. (1) Stereoselective adsorption of impurities on growing crystals sometimes enhanced growth of crystals of a single AA enantiomorph. This led to conglomerates and not separated enantiomers. The supersaturated solutions would not have existed naturally and, worse, an excess of one L-AA would have enhanced forming D-AAs of a different racemic AA. (2) *α*-Methyl AAs with a slight excess of L-enantiomer are seemingly provided by meteorites. Transamination between ketoacid and L-*α*-methylvaline led to the biologically *wrong* D-AAs. (3) The *correct* enantiomers were later obtained using an unrealistically high proportion of a copper catalyst. Extrapolating to plausible concentrations showed that the enantiomeric excess (e.e.) obtainable would have been insignificant. Furthermore, under the optimized conditions, any e.e. produced would have racemized within hours. (4) Simulating wet-dry cycles in a geothermally heated rock pool containing L-AAs in montmorillonite together with L-isovaline led to rapid racemization of the AAs. Therefore, chirality could not be transferred from L-isovaline to produce L-AAs.

Enhanced chirality using single enantiomer amino acid impurities

Most biological amino acids (AAs) form crystals composed of a racemic mixture of the D- and L-enantiomers, but some AAs form conglomerates of individual (*S*) and (*R*) crystals from highly concentrated aqueous solutions. Impurities which adhere to one or more faces of the crystal can hinder further crystal growth in that direction, leading to crystals having visibly different morphologies which can be manually separated. Addadi *et al.* reported some experiments using hot supersaturated solutions of (*R*,*S*)-asparagine (i.e. racemic Asn) in the presence of optically pure glutamic acid, aspartic acid, and glutamine.[1] After 1–2 days crystals formed spontaneously upon cooling to room temperature, with crystals displaying two different morphologies. The minor variant always contained more Asn with the same chirality as that of the additive.

The same behaviour was also documented using (*R*,*S*)-threonine in the presence of small amounts of (*S*)-Glu or (*S*)-Asn. The composition of the two crystal types was confirmed by crystallizing pure (*S*)-Thr concurrently with (*R*)-Glu or (*R*)-Asn, and then in other experiments using pure (*S*)-Thr doped with (*S*)-Glu or (*S*)-Asn.[1]

The effect was due to stereoselective adsorption on the surface of growing crystals of the enantiomer having the same configuration, which slows down its growth, favouring more of the other enantiomorph being produced.[2] The effect required a strong resemblance in stereochemistry and structure between the additive and the enantiomer to be crystallized.[2] To illustrate, (R)-glutamic acid is known to crystallize preferentially from a racemic mixture in the presence of (S)-aspartic acid. These AAs differ by only a CH_2 in the side chain (see figure 1 A). As another example, (R,S)-threonine (Thr) was resolved when using Glu, Asn, Asp or Cys of a single enantiomer (see figure 1 B).[3]

Since additives and monomers incorporated into a crystal tend to bind more tightly if they have the same stereochemistry, the resulting layer won't dissolve away as easily as when mixed enantiomers are used. The pure crystals of that enantiomeric type are thus hindered from forming.[3]

The results of resolution experiments of (*R*,*S*)-asparagine (Asn) crystals in the presence of optically pure amino acids at various concentrations are shown in table 1.[2]

Crystallization was performed by cooling solutions of the racemic AA at twice the concentration of saturation with additives below their solubility limit. Typically, the AA and additives were suspended in an aqueous solution at 40°C and stirred until completely dissolved, then slowly cooled to room temperature.[2] In experiments when seeds were added to facilitate crystallization, 5% of the desired enantiomer or 10% of the R,S seeds were added to the solutions at 40°C.

Other experiments beginning with (R,S)-threonine also produced crystals of the same enantiomeric type in the presence of pure enantiomers of Asn, Glu, Cys-HCl, Asp, His-HCl, Lys-HCl, and Phe. In addition, (R,S)-glutamic acid hydrochloride was resolved by several pure AA enantiomers, including Lys, His, Ser, Cys, Leu, and Tyr. The authors point out:

> "In all cases, however, when crystallization is left to proceed for a long time or its rate is enhanced by vigorous stirring, racemic mixtures of crystals are obtained, thus confirming the exclusively kinetic nature of the resolution process."[2]

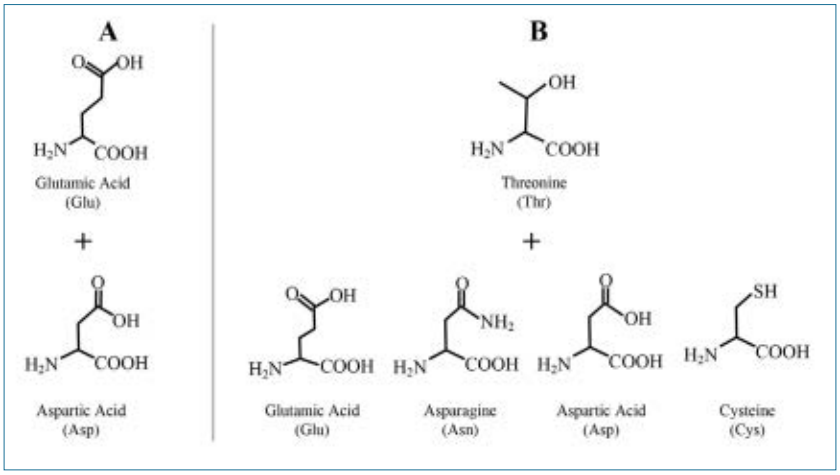

Figure 1. Some racemic amino acids can be resolved by doping with a single enantiomer of a structurally similar amino acid. A: Glutamic acid can be resolved by aspartic acid. B: Threonine can be resolved by glutamic acid, asparagine, aspartic acid or cysteine.

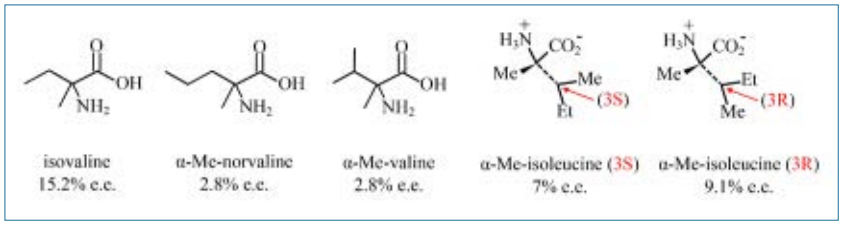

Figure 2. α-Methyl amino acids found on the Murchison chondritic meteorite which have the S configuration (generally referred to as the L-enantiomer) and their % enantiomeric excess (e.e.). Based on figures found in refs. 10 and 13.

The graphical data in the paper confirmed that racemization was almost complete within just a few hours, even without stirring or shaking.[2]

Critical evaluation

- The enantiomorphs which sometimes formed remained intimately mixed as conglomerates and in the same enantiomeric proportions overall. No isolation of D-AAs was achieved.
- These kinds of processes would be devastating for Origin of Life (OoL) purposes, since if the desired excess of L-AAs could have somehow arisen, they would have inhibited growth of crystals of similar AAs containing L-enantiomers. (The change in D vs L content of the large *solution phase* would be negligible, so this would not be a method to enrich L-AAs). It has been known for many decades that small amounts of impurities at the surface of growing crystals can slow down crystallization rates by several orders of magnitude.[4]
- Generating super-saturated solutions of (R,S) AA solutions by chance is implausible, and the different proportions of D vs L in two enantiomorphs would be only short-lived.

One should keep this work in mind when reading about amplification processes which require pure AAs. Proteins require 19 kinds of L-only AA enantiomers, but they would have interfered with each other's enrichment.

Enhanced chirality via amino acid and sugar synergisms

In part 2 of this series, we discussed the effect of biological D-sugars on enantioselectivity of AAs and why this does not provide an answer to the origin of pure L-AAs.[5] Sugars have also been used in other OoL experiments, as we will see next.

Some meteorites of the carbonaceous chondritic type deliver unusual AAs with α-methyl groups, which have an excess of the L-isomers.[6–9] It has been proposed that this e.e. could be transferred to biological AAs. Breslow has also shown that decarboxylative transamination reactions under special conditions alleged to be relevant for a prebiotic world could also produce these kinds of AAs, having a preference for the L-isomer.[10,11]

Chirality transfer using L-α-methylvaline

In 2010 Breslow *et al.* claimed:

"We show how the amino acids needed on prebiotic earth in their homochiral L form can be produced by a reaction of L-alpha-methyl amino acids—that have been identified in the Murchison meteorite—with alpha-keto acids under credible prebiotic conditions."[12]

In the same paper they also stated:

"… with our results, we think we can make a good case that there is a credible story for this origin of homochirality in the prebiotic world. It has the advantage—over various hypothetical ideas—of being a proposal for which there is significant evidence."[12]

As we will see, this is overstating matters, since they actually obtained the wrong enantiomers in excess (D-AAs) and had to experiment extensively to find some special conditions to obtain the opposite of what would be produced naturally. They do admit candidly:

"Apparently no alpha-keto acids have been found in the meteoritic deposits, so our process is relevant only if we can explain how they could arise."[12]

Table 1. Enantiomeric excess from (*R,S*)-asparagine (Asn) in the presence of optically pure amino acids at various concentrations. 300 mg / 3 ml Asn was used at room temperature.[2]

Exp.	Amino acid additive	Additive, mg/mL	Crystal yield, %	$[\alpha]_D$, deg	(*R*) ee configuration	Crystal morphology	Time before filtration, days	Seeds to start crystallization
1	(*S*)-Asp	16.6	14	−29.9	98.0	prisms	2	*R,S*
2	(*S*)-Asp	6.6	17	−23.7	77.7	prisms and plates	4	
3	(*S*)-Asp	3.3	38	−9.6	31.4	prisms and plates	4	
4	(*R*)-Asp	6.6	6	+30.5	100	prisms	6	
5	(*S*)-Glu	16.6	22	−26.0	85.2	prisms and polyhedra	4	
6	(*R*)-Glu	17.0	14	+24.2	79.3	prisms and polyhedra	6	
7	(*S*)-Ser	25.0	21	−15.8	51.8	prisms and octahedra	4	*R,S*
8	(*S*)-Ser	16.6	33	−17.1	56.1	prisms and octahedra	1	*R,S*
9	(*S*)-Ser	8.3	43	−8.8	28.8	prisms and octahedra	1	*R,S*
10	(*S*)-Lys-HCl	33.3	25	−14.7	48.2	prisms and octahedra	7	
11	(*S*)-Lys-HCl	8.3	53	−7.7	25.2	prisms	1	*R,S*
12	(*S*)-His-HCl	16.6	48	−21.3	69.8	prisms and octahedra	1	*R,S*
13	none		43	0	0	prisms	2	
14	(*S*)-Glu	17.0	34	0	0	powder	2	

In other words, they did not begin with the data and conditions expected in meteorites or a prebiotic Earth to evaluate what would result naturally, but invested considerable expertise to design reaction conditions in a laboratory, which could be set up just right to produce the desired outcomes.

Let us review these interesting experiments. Breslow and his team proposed that *α*-methyl AAs found on meteorites, such as shown in figure 2, could transfer their chirality in the synthesis of biological AAs.[10]

Any meteorite plunging through the earth's atmosphere would arrive with the ~10 K temperature or so of space in its interior but would be heated on its outside by friction. "However, the thermal conductivity of chondrites is so low that the inner core would retain a temperature well below 0°C", and thus organic molecules near the core would not be expected to be destroyed through heating.[12]

The non-methylated AAs, as used by proteins, found in carbonaceous chondritic meteorites were found to be racemic.[10]

Some *α*-methylated AAs delivered to Earth by meteorites seem to possess up to 15% e.e.$_L$ of non-terrestrial origin. Breslow and Levine reasoned that perhaps this excess could be transferred to form L-AAs. They experimented with D-*α*-methylvaline reacted with pyruvate and with phenylpyruvate salts, to form alanine and phenylalanine respectively (see figure 3). They wished to see if an e.e. would result and, if so, of which handedness.[14] The hope was to transfer excess L-*α*-methylated AAs formed to produce biological L-*α*-H amino acids. D-*α*-methylvaline was used in the experiments, but the L alternative was expected to produce the mirror effect, a reasonable assumption, which nevertheless should be confirmed.

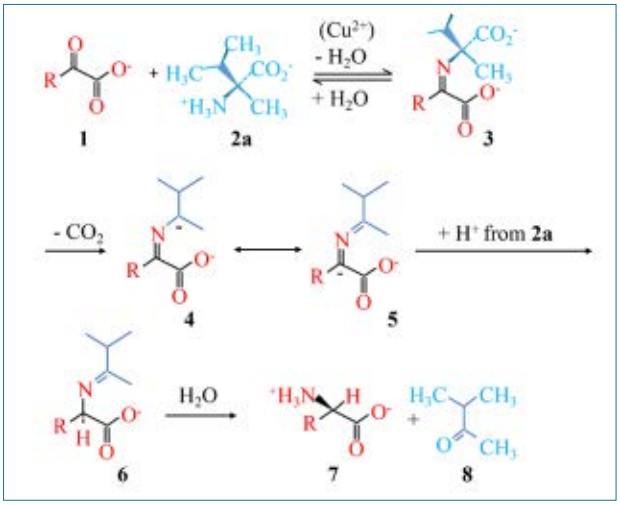

Figure 3. Transamination between ketoacid (1) and *α*-methylvaline (2a) to form amino acids. For 1: sodium pyruvate (R = methyl) or sodium phenylpyruvate (R = Ph-CH_2) were used.[10,14]

Table 2. Enantiomeric excess of L-phenylalanine generated by the reaction of phenylpyruvate and D-α-methylvaline as a powder mixture at high temperature[a,14]

Temperature	1 min	5 min	10 min	30 min
100°C	[b]	9.5 ± 1.5%	9.4 ± 1.6%	6.87 ± 0.01%
120°C	8.3 ± 1.2%	6.0 ± 0.6%	5.8 ± 1.7%	3.5 ± 0.7%
160°C	4.0 ± 1.1%		Racemic	

[a]All values are enantiomeric excess of L-amino acid and the average of 2 runs.

[b]The chemical reaction did not occur.

In the mechanism shown in figure 3, the α-methylvaline performed the transamination that converted a ketoacid to an AA and provided the proton to the α-carbon of the product AA in a stereoselective manner.

The researchers used first D-α-methylvaline and sodium pyruvate in solution but failed to obtain any transamination product. In the next attempts they dissolved the reactants in a methanol/ethanol mixture or in water to produce a well homogenized mixture; then the solvent was removed. The resulting solid was heated to temperatures ranging from 100 to 160°C for 1 to 30 mins, which the authors claimed, "mimics the common prebiotic concept of chemistry in a dried lake bed".[14] Finally, the imine produced was hydrolyzed.

Using sodium pyruvate produced at most 3% $e.e._L$ alanine under all the times and temperatures tested (R = methyl in figure 3), but slightly higher selectivity was obtained using sodium phenylpyruvate (R = Ph–CH_2 in figure 3), see the results in table 2.

Since using D-α-methylvaline produced a slight excess of an L-AA, using instead L-α-methylvaline, as allegedly found in meteorites, must produce the biologically *wrong* D AAs. Noteworthy also is that the $e.e._L$ of phenylalanine decreased with increasing temperature and over time on the timescale of only minutes.

Reacting in a dry state minimized providing protons which would facilitate racemization. In fact, when the reactions were carried out on montmorillonite clay, no e.e. resulted, presumably because protons could now be provided from different directions.

An alternative scenario proposed would use α-methyl AAs of extraterrestrial origin to catalyze formation of some D-sugars, as Pizzarello and Weber have done and then use those sugars to catalyze the formation of the normal L-AAs.[15] However, credible prebiotic examples of the latter process have not yet been produced.[13]

Critical evaluation

- L-α-methylvaline did not lead to the hoped-for L-alanine and L-phenylalanine. These experiments were claimed to have been executed under prebiotically realistic conditions but provide examples of how an $e.e._D$ of AAs could have been produced; i.e. of the wrong handedness for biological purposes. This would make the generation of an excess of L-AAs even more difficult.
- These experiments provided examples of how researchers can manipulate reaction conditions to obtain the results desired. The reactions were terminated quickly since it was apparent that racemization was occurring rapidly. An e.e. which only lasts a few hours would not lead to plausible OoL models.

Chirality transfer using L-α-methylvaline with a copper catalyst

In a new series of experiments, instead of using a 2.8% e.e. L-α-methylvaline as found in a meteorite, Breslow *et al.* began with an $e.e._L$ of 96% which, when reacted with phenylpyruvate, led to L-phenylalanine with up to 37% e.e., and when reacted with pyruvate, produced L-alanine with up to 20% e.e. In these experiments the scheme in figure 3 was modified to include a copper sulphate catalysis in extremely high concentration. Both copper and zinc are present in some meteorites and in low average concentrations on Earth, but with zinc (II) the researchers obtained the same result as without a metal ion, namely a small amount of formation of the *wrong* D-AA![12]

This novel copper-catalyzed decarboxylative transamination was also used to synthesize L-valine from L-α-methylisoleucine.[10]

Were these designed experiments representative of what would occur under unguided conditions? The transamination reaction in the presence of copper (II) sulphate was carried out using 1 equivalent of cupric sulphate, 1 equivalent of sodium pyruvate or sodium phenylpyruvate, and 4 equivalents of α-methyl AA dissolved in water. The reaction mixture was *stirred* at room temperature to ensure complete dissolution, and the parent reaction mixture was then subdivided into vials (approximately 10 mg/vial). Water was removed from the vials in vacuo, and the resulting solid reaction mixtures were heated for various times and temperatures.[10] One of the products was an *amino acid*, see figure 3.

Anhydrous copper (II) sulphate is found naturally as the very rare mineral chalcocyanite. No information was provided for the effectiveness under these experimental conditions when various alternative copper (II) sulphates are used, which have the chemical formula $CuSO_4(H_2O)_x$. These crystal minerals are also rarely found in nature, though.

Table 3. Enantiomeric excesses of L-amino acids produced from the pathway shown in figure 3 in the presence of extremely high cupric sulphate. Data from the Supplemental Materials of ref. 10.

A. L-phenylalanine by reacting L-*α*-Me-valine and sodium phenylpyruvate with cupric sulphate.						
Time (min)	**120°C L-e.e., %**	**Error margin**	**140°C L-e.e., %**	**Error margin**	**160°C L-e.e., %**	**Error margin**
1	4.6	±2.7 (2 trials)	0.0	(3 trials)	0.0	(3 trials)
5	0.0	(3 trials)	6.3	±4.2 (3 trials)	15.1	±1.1 (3 trials)
10	0.0	(3 trials)	8.4	±4.0 (3 trials)	10.5	±1.1 (3 trials)
30	6.1	±2.3 (3 trials)	14.1	±8.5 (3 trials)	32.0	±20.3 (3 trials)
45	2.2	±0.4 (3 trials)	2.6	±1.8 (3 trials)	33.3	±18.5 (3 trials)
60	4.7	±2.9 (3 trials)	13.6	±13.9 (6 trials)	37.0	±14.8 (3 trials)
120	5.6	±6.1 (2 trials)	23.3	±12.9 (4 trials)	26.5	±17.1 (3 trials)
Average:	2.2		6.2		11.6	
B. L-alanine by reacting L-*α*-Me-valine and sodium pyruvate with cupric sulphate.						
Time (min)			**140°C L-e.e., %**	**Error margin**	**160°C L-e.e., %**	**Error margin**
1			4.9	±2.9 (2 trials)	3.7	±2.7 (2 trials)
5			14.1	±21.7 (3 trials)	5.0	±4.0 (3 trials)
10			9.4	±6.2 (3 trials)	11.8	±4.9 (3 trials)
30			6.9	±6.1 (3 trials)	23.0	±13.8 (2 trials)
45			8.3	±1.6 (3 trials)	8.9	±5.5 (3 trials)
60			16.9	±9.5 (3 trials)	19.6	±5.1 (3 trials)
120			19.6	±5.0 (2 trials)	12.9	±7.6 (3 trials)
		Average:	11.4		12.1	
C. L-valine by reacting L-*α*-Me-isoleucine and sodium 3-methyl-2-oxobutanoate with cupric sulphate.						
Time (min)			**140°C L-e.e., %**	**Error margin**	**160°C L-e.e., %**	**Error margin**
1			7.7	±6.7 (3 trials)	0.6	±1.6 (3 trials)
5			--		0.6	±0.4 (2 trials)
10			--		1.2	±0.6 (3 trials)
30			1.1	±0.3 (3 trials)	3.6	±2.4 (3 trials)
45			1.1	±2.4 (3 trials)	6.9	±2.5 (3 trials)
60			3.2	±1.3 (3 trials)	7.0	±1.4 (3 trials)
120			7.5	±5.0 (3 trials)	11.3	±10.7 (3 trials)
		Average:	3.2		7.2	

Yields were not reported. A variety of reaction times (1–120 mins) and temperatures (120–160°C) were screened, and the best results were obtained at 160°C for 60 mins, wherein L-phenylalanine was obtained in 37% e.e. Shorter reaction times or lower reaction temperatures led to much lower e.e.s.[10]

The authors admitted a key point:

> "*Heating 96% enantiopure L-R-methylvaline with sodium pyruvate and cupric sulfate at 160°C for 60 min under solvent-free conditions yields L-alanine in 20% ee. In the absence of copper, only low ee's of the undesired D-alanine were obtained.*"[10]

L-α-methylisoleucine (found on meteorites in 7.0% $e.e._L$) reacted with 3-methyl-2-oxobutanoate also in the presence of high proportions of cupric sulphate to produce L-valine with up to 23% e.e. "In the absence of copper, no reaction occurred."[10] Also, zinc salts did not lead to the reversal of chiral introduction they obtained using the copper catalyst.

The authors had succeeded in finding conditions which reversed the enantioselectivity found in the earlier work,[14] whereby L-α-methylvaline with a copper catalyst now led to L-phenylalanine preferentially. The authors claimed that the reaction conditions (solvent-free, 120–160°C) mimicked plausible conditions on prebiotic Earth.[10] However, upon eventually encountering water at such high temperatures, the L-AAs produced would have racemized rapidly, on a timescale of days.[16–19]

Recall that no α-keto acids have been found in the meteoritic deposits, and these would have had to be available in a free chemically unbounded form in order to react. So, at best these would have been present in ppb concentration in a minority of meteorites. Suitable α-methylamino acids would also be available in only very low concentrations. After the meteorite had broken into pieces while hurtling through the atmosphere and then crashing unto the earth, both classes of material would have been further diluted by orders of magnitude in terrestrial water or crust. Both chemicals would almost always be present concurrently in the *absence* of Cu in a suitable salt form, leading to the *wrong* D-AAs. Cupric ion does accelerate the decarboxylation process, but this cannot compensate for the vastly greater degree of reaction which would have occurred in the absence of a suitable copper catalyst overall.[12] This is a highly contrived and implausible scenario to generate a reliable source of L-AAs to create proteins for a primitive life-form.

The relative e.e. would also have been drastically diluted through mixing with existing racemic amino acids, so that millions of years would have been needed to have accumulated the minimum concentrations needed, during which time all AA e.e. would have been lost through racemization.

Destruction of any L-e.e. produced

Elevated temperatures such as required by these experiments would not have permitted crystallization in a drying lakebed near a site of meteorite landing to produce amplification.[10] What are we to make of the statement that "the best results were obtained at 160°C for 60 min"? They did not draw attention to the fact that a plateau was reached at this very short time. 'Best results' suggest that conditions removed from these times and temperatures produced less of the amino acid and/or lower e.e., so I examined the Supplemental Materials provided. The results are summarized in table 3, referring to the reaction pathway shown in figure 3 to produce some L-amino acids.[10]

Let us review the results summarized in table 3.

Production of L-phenylalanine

From table 3 A we observe that enantiomerically *pure* L-α-Me-valine added to sodium phenylpyruvate was able to transfer a maximum of 37% chirality to L-phenylalanine when reacted at precisely 160°C for 60 minutes. If not then quickly removed from the heat, more than 10% of the e.e. was lost within just one hour. Of course, the e.e. of L-α-methyl valine found in the Murchison meteorite was not 100% but only 2.8%. The total amount present in a meteorite would have been in the ppb range; not all of it would have leached out immediately at the crash site; and all or most would have remained in large complexes. The conclusion is unavoidable that even under the best possible conditions <<1% e.e. L-phenylalanine could have been produced this way at some terrestrial location.[12]

It is absurd to expect a meteorite to crash and produce an environment around exactly 160°C for just one hour. Suppose the temperature was lower. The results reported for 120°C seem to vary randomly. An $e.e._L$ of 4.6% was found after 1 minute, but none for five and for 10 minutes. The values found between 30 and 120 minutes don't follow any trend. Given that one hour was ideal at 160°C, what $e.e._L$ would have resulted at 120°C? Only about 4.7% instead of 37% chirality could have been transferred assuming an unrealistic ideal stochiometric proportion.

The results from the higher temperature of 140°C were also not promising; for example only ~3.2 % e.e. L-valine was produced on average for durations of 30–120 minutes.

The authors concluded that a temperature around 160°C produced the highest e.e. values when forming phenylalanine.[10] But this creates a dilemma. From table 3, in two out of three of the AAs, going from one hour reaction time to two hours significantly *decreased* the $e.e._L$. (Except for table 3 C, the error margin is about the size of the e.e. itself, and the e.e. of alanine was the smallest of the AAs reported). The OoL community is searching for a natural

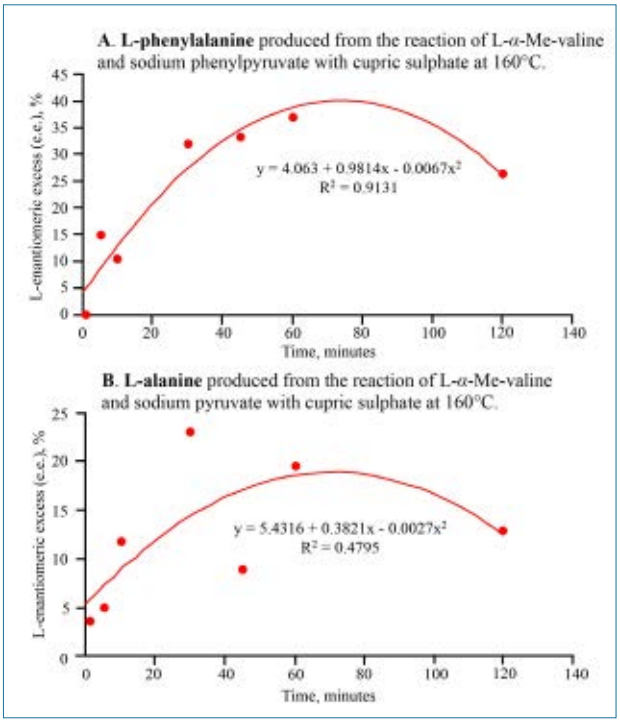

Figure 4. The data from tables 3 A and B at 160°C demonstrate that after only a few hours under the best reaction conditions all or most of the enantiomeric excess would have been lost. Data from the Supplemental Materials of ref. 10. Curve fitted using a second order polynomial function with Excel. Average of 2 or 3 trials from ref. 10 were used.

way to produce 19 AAs with high $e.e._L$ but the e.e. produced would have been rapidly destroyed. Figure 4 shows that within only a few hours at 160°C, the e.e. would have been entirely eliminated.

Under unguided natural conditions, these materials, at temperatures of 120–160°C, would eventually come in contact with water where racemization would be very rapid.[16–19] There are many realistic scenarios where AAs would be exposed to high-temperature water, such as in or near hydrovents.

Production of L-alanine

From table 3 B, enantiomerically pure L-α-Me-valine added to sodium pyruvate transferred a maximum of 19.6% at 140°C when exactly 120 minutes was used. The highest e.e., 23% transfer, was achieved at 160°C when exactly 30 minutes was used, but at all longer durations the $e.e._L$ decreased. The concerns discussed in the section above apply here also.

Production of L-valine

From table 3 C, enantiomerically pure L-α-methyl isoleucine, another meteoritic component, converted sodium 3-methyl-2-oxobutanoate to L-valine with a maximum e.e. of 11.3% (at 160°C and 120 minutes). At 140°C, an e.e. of 7.7% was obtained after 1 minute. But then at 30 and 45 minutes, the valine was about racemic within experimental error. Of all the experiments only the e.e. results for valine were not reported at 5 and 10 minutes. After 120 minutes an e.e. of 7.5% was reported, almost as high as found at 1 minute. Unfortunately, reaction times of a few days were not reported, in particular for 160°C, to see when loss of e.e. becomes apparent. Individual values were not provided nor was the meaning of ±, which might mean a range or standard deviation. The huge error margin of ±10.7 at 160°C raises the concern of a single unrepresentative outlier distorting the results.

As mentioned above, when Breslow and Levine used 100% R α-methylvaline to transaminate α-keto acids they obtained AAs with insignificant e.e. (L-alanine with ~3% e.e., and L-phenylalanine with ~9.5% e.e.).[14]

Critical evaluation

In addition to the realities presented above, which demonstrate that the authors have reported a laboratory artefact which would not have occurred naturally, we would like to emphasize three facts.

- In the absence of the extremely high proportion of copper catalyst, only small e.e. of the 'wrong' D-alanine were obtained.[12] The probability of finding exactly all the best components concurrently is much lower vs. all except for the Cu catalyst. The occurrence of all these events would have averaged out to a net excess of the wrong AA enantiomers.
- Clearly the transamination of α-keto acids to transfer a small fraction of chirality from pure *R* α-methylvaline to form AAs was only a laboratory artefact with no plausible relevance for OoL purposes.
- We have here an example of the often-observed fact that to obtain an e.e. another molecule possessing a much higher e.e. must be used.

Acceleration of amino acid racemization by isovaline (Iva)

In a popular evolutionary scenario, rock pools on active volcanic islands before permanent continents had formed provided favourable locations for prebiotic organic reactions.[20] Allegedly, large amounts of organic compounds could have accumulated in high concentrations, instead of being diluted in the ocean. It is claimed that different types of gradients (e.g. temperature and pH) could have helped drive chemical reactions. Moreover, minerals such as montmorillonite—a weathering product of basaltic material—could have affected the behaviour of some reactions. For

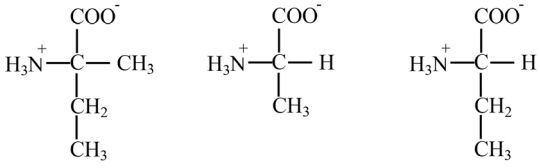

Figure 5. Structures of the L amino acids used in this study: Iva (2-amino-2-methylbutanoic acid), Ala (2-aminopropanoic acid), and Abu (2-aminobutyric acid).[22]

example, the intercalation of AAs hinders their sublimation at higher temperatures.[21] Some OoL researchers propose that the source of L-AAs derived from chirality transfer from *α*-methyl variants of proteinogenic AAs. For example, Breslow and Cheng claim:

> "… evidence has now accumulated that the L handedness of amino acids was derived from a special group of amino acids, with an extra methyl group that prevented loss of their small excess of the L form."[11]

This brings us to some experiments conducted by Fox *et al.* at the University of Hohenheim in Germany and reported in 2020. The experiments were designed to model a geothermally heated rock pool containing AAs in montmorillonite.[22] The team examined the effect of D- and L-isovaline (L-Iva) on the thermal racemization of L-alanine (L-Ala) and L-2-aminobutyric acid (L-Abu), see chemical structures in figure 5.

The AAs were integrated into the clay mineral calcium montmorillonite at 150°C. Recall from above that non-natural *α*-methylated AAs such as isovaline are believed to have possessed a small $e.e._L$ in meteorites landing on Earth.

The L-Ala used was almost 100% enantiopure initially. Remarkably, merely upon loading into montmorillonite, the L-e.e. decreased by a few percent (but this did not occur for L-2-aminobutyric acid (L-Abu)). This effect was particularly pronounced for the experiment using only 0.5% Ala, where the L-e.e. dropped to 86.7%, even though the temperature did not exceed 35°C. Such rapid racemization (within hours) at a low temperature had already been observed during multiple wet-dry–cycle experiments when loading into montmorillonite.[20]

In a series of tests, different Iva-to-Ala molar ratios (1:1, 3:1, and 5:1) were used to monitor the racemization of L-Ala over a period of 8 weeks. About thirty L-e.e. values were measured, leading to smooth trend curves with L-e.e. decreasing over time.[22] The rate of racemization increased with increasing concentration of Iva. When 0.5%-pure L-Ala enantiomer was used, in the absence of Iva, the L-e.e. dropped to 61.0% after eight weeks. In the presence of L-Iva, final L-e.e. values of Ala decreased to 47.6% (1:1 Iva-to-Ala molar ratio), 41.8% (3:1) and 29.9% (5:1) (see table 4).[22]

The same trends were obtained when 0.5%-pure D-Iva enantiomer was mixed with L-Ala, but for all three molar ratios the rate of racemization was less pronounced (see table 4).[22]

The smaller effect of D-Iva compared to L-Iva was also observed when higher concentrations of L-Ala and of L-Abu (2%) were used in 1:1 molar ratio with each of the Iva enantiomers, as shown in table 4.[22]

HPLC analysis showed that decomposition and sublimation were not a significant issue short-term, since, in all cases, at least 67% of the initial Ala and Abu were still present after the 8-week-long experiments. Of course, decomposition over deep time would have destroyed the AAs in these kinds of environments with fluctuating temperatures.

The acceleration in racemization seems to be due to direct interaction between two AA molecules. The higher the concentrations, the faster this occurred. Hydrogen-bonded L-Ala or L-Abu–Iva dimers would exist as two L–L and

Table 4. Rate of racemization of L-alanine and L-2-aminobutyric acid by D- and L-*α,α*-dialkyl amino acid isovaline

0.5% Ala			
L-Iva: L-Ala	**L-e.e. final**	**D-Iva: L-Ala**	**L-e.e. final**
0	61.0%	0	61.0%
1:1	47.6%	1:1	51.0%
3:1	41.8%	3:1	45.8%
5:1	29.9%	5:1	34.0%

2% Ala or Abu	
***α*-H-amino acid + Iva**	**L-e.e. final**
L-Ala	46.2%
L-Ala + D-Iva (1:1 molar)	35.0%
L-Ala + L-Iva (1:1 molar)	29.9%
–	–
L-Abu	52.9%
L-Abu + D-Iva (1:1 molar)	43.3%
L-Abu + L-Iva (1:1 molar)	36.8%

Ala: alanine
Abu: 2-aminobutyric acid
Iva: *α,α*-dialkyl amino acid isovaline

L–D diastereomers, where, for steric reasons, the L–D dimer apparently forms less readily than homodimers.[22]

The authors found that D- and L-Iva molecules are more effective at accelerating racemization of L-Ala than a second L-Ala molecule. The reasoning is based on data from table 4.

i. When 0.5% L-Ala was mixed 5:1 Iva:Ala molar ratio, an e.e.$_L$ of 29.9% was obtained when mixed with L-Iva but 34.0% with D-Iva.
ii. The same L-e.e. values were obtained, within experimental error, when 2.0% L-Ala concentration was mixed 1:1 molar with L-Iva and then with D-Iva. This is remarkable, since comparing i) and ii) shows that much less L-Ala was used in i (0.34 mmol) than in ii (1.4 mmol), whereby the compensating greater amount of L- or D-Iva was small: 1.7 mmol for i) vs 1.4 mmol for ii).[22]

The mechanistic basis for Iva causing faster racemization of L-Ala than a second L-Ala was unknown. Deprotonation at the α-C atom to form a carbanion is the most common mechanism for AA racemization and is catalyzed by a Bronsted base. The negative charge withdrawing carboxylate group of a second (zwitterionic) AA may assist the deprotonation step. A hydrogen-bonded dimer involving the carboxylate group of the AA Iva might be more basic and/or have better proton accessibility than L-Ala in the L-Ala–L-Ala interaction.[22]

We agree with the authors' conclusion:

> "Accelerated racemization of amino acids could have been an obstacle to the development of homochirality."[22]

Under natural conditions, the loss of chirality would have been slower since the conditions were optimized for laboratory convenience. But complete racemization would have occurred eventually for AA trapped in such hot, rocky crevices, which survived thermal decomposition. There would not have been a transfer of chirality from L-Iva to racemic AAs to generate more of the L-enantiomer.

These results contradict the results reported above[10] and confirm that the unnatural L-methylated AAs delivered by meteorites would have catalyzed formation of the biologically *wrong* D-AAs. The experiments producing the *wrong* AAs were far more likely to resemble a putative prebiotic Earth.

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Are solar-driven forces sufficient for Hydroplate Theory asteroid origins?

Edward A. Isaacs

Though comets, asteroids, and TNOs comprise an ongoing mystery for secular and biblical cosmogonies alike, Hydroplate Theory (HPT) emphasizes an origin closely tied to its mechanism for the Genesis Flood. It theorizes that granitic fragments launched from the posited antediluvian crustal shell by the fountains of the great deep formed swarms that coalesced into minor planets (asteroids and trans-Neptunian Objects) and other such bodies. However, the energy available for placing these swarms into their orbits about the sun is simply not present within the HPT Earth System. Instead, HPT proposes that swarms were acted upon by passive solar-driven forces including solar wind, solar radiation pressure, and temperature-driven gas pressure to expand the swarms' orbits. Solar radiation pressure, despite difficulties quantifying it, seems to be irrelevant, since it relates to materials with high specular reflection rather than diffusive reflection seen on minor planets and comets. What can be quantified of these passive forces, however, remains insignificant except over timescales exceeding tens of thousands of years. With the minuteness of these contributions, it remains uncertain how passive forces could overcome HPT's lacking energy budget. The formation of asteroids, TNOs, and comets remains an elusive problem for the HPT concept.

The existence and origin of the lesser solar system bodies like asteroids and comets continues to befuddle secular and biblical cosmogonies alike.[1] In creationist circles, research tends to emphasize an origin contemporaneous to Earth during the Creation Week and/or some role in the initiation of the Flood.[2–5] However, one model proposes that the Genesis Flood played a hand in the origin of asteroids and comets: Hydroplate Theory (HPT). Encapsulating asteroids, meteoroids, comets, and trans-Neptunian Objects (TNOs), HPT envisions their origin as agglomerations of terrestrial water and granite fragments launched into the solar system by the 'fountains of the great deep' (Genesis 7:11) during the Flood. The brainchild of Dr Walter T. Brown, HPT has been revised through nine editions of Brown's *In the Beginning*,[6] gaining a strong focus on astronomical phenomena despite its apparent geological emphasis.[7]

HPT proposes that the antediluvian Earth maintained a solid basalt mantle overlain by an interconnected series of subterranean water channels, averaging 1.6 km thick, beneath an overarching 100-km granitic shell that encircled the globe (figure 1). It is from this granite shell that HPT postulates that interplanetary debris, including comets, meteoroids, asteroids, and TNOs, arose due to crustal breakup at the onset of the Flood. As the supercritical subterranean water was released through fractures in the granitic shell as the 'fountains of the great deep' (Genesis 7:11), eroding fragments were launched along with the sustaining jets of water that continuously expelled portions of the granite shell into the solar system (figure 2).[8]

Such activity during the Flood would require enormous energy sources. Such sources of energy, however, are severely lacking within the HPT Earth System. As described in Carter and Isaacs,[9] energy sources from gravitational potential energy and accelerated radionuclear decay, though representing the largest reservoirs of energy within the HPT Earth System, are too limited to fuel the launch of granitic shell fragments into their current positions. With the insufficiency of energy reservoirs within the antediluvian Earth System, HPT must look further afield. As described in various editions of Brown's synthesis, HPT relies on passive solar-driven forces to complete the journey from granitic projectiles to fully fledged comets, asteroids, and meteoroids. These passive solar-driven forces are collectively referred to as the 'radiometer effect'.

The radiometer effect: a three-fold system of passive solar drivers

The radiometer effect, as described by Brown, encapsulates three individual yet related processes driven by the sun. After escaping the bounds of Earth, granite fragments and accompanying debris are left to the vacuum of space where the sun may become a primary agent in the succeeding journey of the resulting agglomerations. As Brown describes:

> "The fountains of the great deep launched rocks as well as muddy water. As rocks moved farther from Earth, Earth's gravity became less significant to them, and the gravity of nearby rocks became increasingly significant. Consequently, many rocks, assisted by their

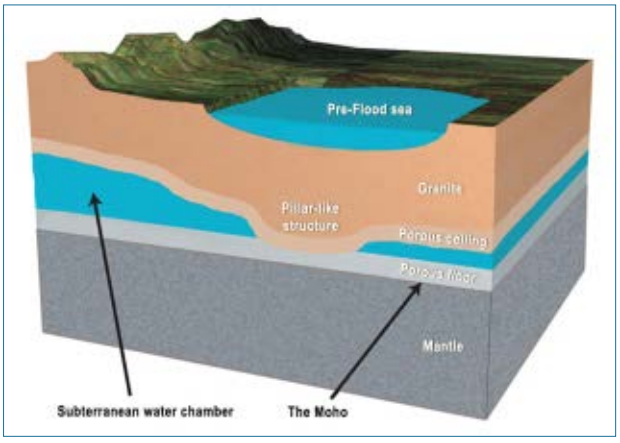

Image: Steve Daniels

Figure 1. Depiction of Hydroplate Theory's proposed crustal structure before the Genesis Flood with its globe-encircling granitic crust measuring 100 km in thickness, capping a highly pressurized subterranean water chamber averaging 1.6 km. (From Brown, ref. 4, fig. 55 on p. 124.

> mutual gravity and surrounding clouds of water vapour that produced aerobraking, merged to become asteroids. Isolated rocks in space are meteoroids. Drag forces caused by water vapour and thrust forces produced by the radiometer effect concentrated most smaller asteroids in what is now the asteroid belt. Larger asteroids were acted on longer by more powerful forces which pushed them out beyond Neptune's orbit. All the so-called 'mavericks of the solar system' (asteroids, meteoroids, comets, and trans-Neptunian objects) resulted from the explosive events at the beginning of the Flood."[10]

With the influx of gaseous water and granite fragments in the vacuum of space, swarms of particles would have begun accumulating around larger granite fragments. Being held together by the gravitational attraction of the larger fragments, swarms would have gradationally grown in mass and gravitational attraction as additional particles were captured and integrated into the swarm. This is somewhat analogous to the accretionary phase of the Solar Nebular hypothesis, with the distinction that enveloping atmospheres of gaseous water around these swarms would have helped aerobrake incoming particles to safeguard against the swarm's destruction upon impact:

> "… each asteroid began as a growing swarm of rocks, ice, and gas orbiting within the sphere of influence of a large 'seed' rock. As its sphere of influence grew, it pulled in more mass and grew even more. Larger swarms intercepted more of the Sun's radiation, especially for a few years after the flood. … the Sun's gigantic energy produced the thrust that spiraled swarms and asteroids outward."[11]

Once swarms began accumulating, they may have been acted upon by the so-called radiometer effect derived by analogy from Crook's famous light mill:

> "This well-known novelty, called a radiometer, demonstrates the unusual thrust that pushed asteroids into their present orbits. Sunlight warms the dark side of each vane more than the light side. A partial vacuum exists inside the bulb, so gas molecules travel relatively long distances before striking other molecules. On average, gas molecules bounce off the hotter, black side with greater velocity and momentum than off the colder, white side. This turns the vanes away from the dark side… . The thrust on the radiometer acts primarily on the vane's hot edges, not the vane's relatively large area. The swarms of tiny rocks and ice orbiting the Sun during and after the flood had an astronomical number of hot edges, so the total thrust on each swarm was greater than on a regular radiometer."[12]

With the radiometer effect built upon the analogy of Crook's light mill, it is necessary to note the limitations of the analogy, beginning with several common misconceptions.[13] First, if the vanes were spinning as a result of the bombarding photons' momentum acting upon the vanes' large surface areas, the vanes would have spun *away* from the light side or in the opposing direction. This is due to light being primarily absorbed by dark colours and reflected by light colours, which would then cause the vanes to spin in a direction opposite to that described above. Likewise, neither side of the vanes are heated more than the other, but instead the gas between the vanes is differentially heated. Indeed, the gas facing the dark sides heats and expands more than the gas on the light faces, causing the gas particles facing the dark sides to strike the edges of the vane obliquely. This imparts more force to edges of the dark side of the vanes, driving the light mill. As such, the effect is not a result of which vanes are warmer or which receive more momentum, but instead how that force is imparted along the vanes' edges.

Notwithstanding the common misconceptions, there are three further limits to the analogy.

1. Even given the innumerable edges to be found within a swarm, those edges are not as crisp or sharp as those found along a light mill's vanes.
2. The reflectivity on opposing sides of the swarm or particles is generally not nearly as great as that along the strongly contrasting light and dark vanes of a light mill.
3. Whatever discrepancy in reflectivity that may exist would be the opposite of that in the light mill. The shadow cast by the swarm or particle would make the more distant side darker than the light-facing side, indicating that the swarm is driven *away* from the light side rather than *towards* the light side as in the light mill.

Nonetheless, by extension of the analogy of Crook's light mill, Brown's radiometer effect may be differentiated

into three interrelated forces driven by the continuous output from the sun.

1. Solar wind

Of the various forms of solar energy available for producing work on swarms, solar wind is the simplest and most direct form. With a nominal pressure of 1×10^{-9} to 6×10^{-9} N/m^2 at 1 AU from the sun,[14] solar wind would exert a distributed load on both granite crustal fragments and released water particles alike. They would consequently be swept towards the outer limits of the solar system at a rate proportional to the area over which solar wind was acting and inversely to the mass of the object and/or associated swarm. Over time, this constant pressure would accelerate swarms on their outward spirals to the Asteroid Belt and TNOs.

2. Solar radiation pressure

Like the radiometer effect, Brown proposes that crustal fragments were propelled both indirectly by light via differential heating as well as directly in a way akin to solar sailing due to solar radiation pressure. In this latter process, the momentum from bombarding photons is absorbed by the projectiles and converted into thrust, thereby spiralling the projectiles further into space:

> "Fourth, a swarm also acted as a solar sail. Photons (particles of light) from the Sun transfer their momentum to orbiting objects they strike. Solar sails are now propelling some spacecraft, and someday may send future spacecraft to a nearby star. Today's solar sails are not much larger than a living-room rug, but a swarm of rocks, ice, and gas would have been thousands of times larger—and provided thousands of times more thrust to steadily accelerate the swarm."[8]

3. Gas pressure

With gaseous water travelling with the granite projectiles in swarms of debris, differential heating of the swarm could cause pressure variations that would add thrust to projectiles towards the outer reaches of the solar system. As Brown explains:

> "Gases, such as water vapor and its components, were abundant in the inner solar system for years after the flood. Hot gas molecules striking each asteroid's hot side were repelled with great force. This jetting action was like air rapidly escaping from a balloon, applying a thrust in a direction opposite to the escaping gas. Cold molecules striking each asteroid's cold side produced less jetting. This type of thrusting, which I call the radiometer effect, was efficiently powered by solar energy and spiraled asteroids outward, away from the Sun, concentrating them between the orbits of Mars and Jupiter."[15]

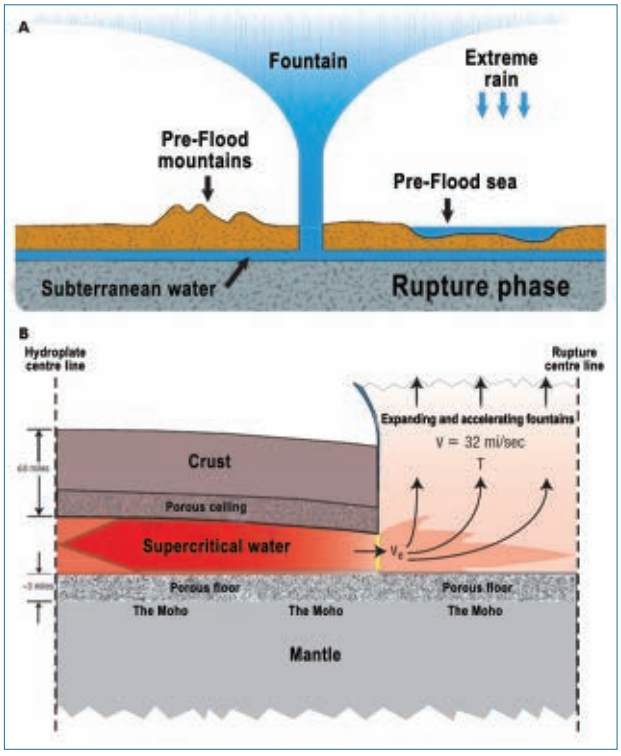

Figure 2. HPT postulates that the release of subterranean water as the 'fountains of the great deep' during the Rupture Phase (A) eroded hydroplate edges and propelled the resulting granitic crustal fragments at speeds greater than Earth's escape velocity (B). Once released into the solar system, these fragments, along with water vapour, would form swarms driven by the radiometer effect into the orbits of comets, meteoroids, asteroids, and trans-Neptunian Objects. (After Brown, ref. 6, figs. 57 and 225.)

In the case of TNOs:

> "... larger swarms had more gravity, so they could hang on to their gases more firmly. Those gases were heated on the day side and, therefore, reached higher pressures than gases on the frigid night side. As long as gases remained, the swarms acted as Carnot [CAR-no] engines, delivering thrust from the greater pressure pushing the swarms away from the Sun. The difference between the heat absorbed by the swarm and the heat rejected (one-half rotation cycle later) became thermodynamic work—a force (thrust) acting through a distance."[11]

Due to the increased concentration of gaseous water spread throughout the solar system, warming from solar radiation on the side of swarms facing the sun would elevate the temperature of the gas in comparison to the gas on the side opposing the sun (that is, in the swarm's 'shadow'). This temperature difference would cause an associated pressure

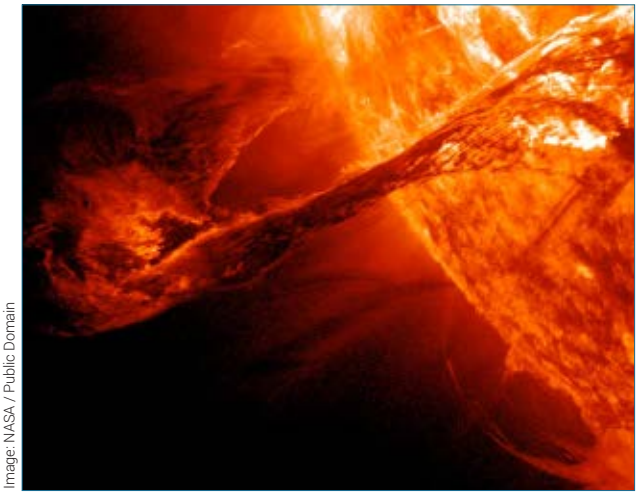

Image: NASA / Public Domain

Figure 3. With insufficient energy within the HPT Earth System to launch swarms into their eventual orbits, HPT must harness energy released from the sun. Firstly, solar wind creates a faint pressure that could propel swarms. Secondly, HPT supposes that solar radiation pressure, the basis of lightsail technology, could drive swarms through absorption of photon momentum. Finally, HPT speculates that pressure differences due to warming on swarms' sun-ward face compared to cooling on the opposing face would spiral swarms outward from the sun due to gas pressure from nascent atmospheres around swarms.

difference. With a higher net pressure due to the higher temperature, the swarm would drift towards zones of lower pressure away from the sun, slowly widening their orbits. This mechanism represents the most significant of the passive solar-driven forces central to the HPT concept.

Are passive forces enough?

Each of these mechanisms play together to form a passive means of harnessing solar energy within asteroid formation (figure 3). Due to the insufficient energy budget within the HPT Earth System,[9] these passive mechanisms must be employed to complete the journey of swarms from Earth to across the solar system, all while passive mechanisms soften and even out the orbits of nucleating swarms.[16] As force is constantly applied, the swarms would gradually gain acceleration, driving them further afield. The question, then, naturally arises: are these passive mechanisms enough? Will a constantly applied minute contribution of pressure grow to adequately fuel swarms on their outward trajectory? The HPT astronomical submodel demands that answer be yes. In his two chapters, Brown conveys several illustrations[17] and mentions unpublished computer simulations[18] suggesting that passive forces do indeed grow to sufficient magnitudes, though a systematic analysis of each individual mechanism is yet to be published. Even so, what has been published provides adequate information to query each mechanism.

Solar wind insufficient

As mentioned in its introduction, solar wind is a weak passive mechanism. Decreasing in strength with further distance from the sun, solar wind has a nominal pressure of 1×10^{-9} to 6×10^{-9} N/m^2 at 1 AU.[14] Assuming no friction in the vacuum of space and that the sun's gravitational influence is negligible, this would indeed cause an outward thrust on agglomerating swarms. Consider a swarm the mass of Ceres,[19] which we define $m_{Ceres} = 9.39 \times 10^{20}$ kg. Ceres currently averages nearly 2.77 AU from the sun, requiring a minimum travel of 1.77 AU or 2.66×10^{11} m from the earth. Let us presume that for this single minor planet, the swarm maintained a radius of 10,000 km (1.00×10^7 m), nearly 50% greater than the earth's radius and 21 times Ceres' current radius. The area of our swarm, then, would be half of the surface area of a sphere (that is, $A_{swarm} = 2\pi r^2 = 6.28 \times 10^{14}$ m^2), as solar wind would only apply pressure onto the sun-facing half of the swarm. That said, the mass density of such a large volume would be quite small (0.153 g/cm^3) compared to Ceres' current density (2.16 g/cm^3) and the density of granite (2.67 g/cm^3). As such, this volume would appear perforated to solar wind which would flow through relatively unhindered, but we shall assume instead that solar wind pressure was distributed across the swarm as if the swarm's volume was, for our purposes, a solid sphere in order to maximize thrust.[20] This solar wind would maintain a constant pressure of $P_{wind} = 6 \times 10^{-9}$ N/m^2. Because pressure is simply force over area while force is simply mass times acceleration, we may know the constant acceleration imparted onto the swarm to be:

$$a = \frac{A_{swarm} P_{wind}}{m_{Ceres}} = 5.9 \times 10^{-15} m/s^2$$

Because distance is only velocity times time while velocity is acceleration times time, we can know that $d = at^2$. Already knowing a, as found above, and d as 1.77 AU, we can solve for t:

$$t = \sqrt{\frac{d}{a}} = 210{,}000\ yr$$

Given even these generous conditions, solar wind alone would require 210,000 years to propel a swarm into the orbit of Ceres, and a journey of 1.77 AU. This pales in comparison to the distance required for a swarm to attain the orbit of TNOs, which average between 30 to 70 AU from the sun. Meanwhile, the swarm is supposed to be collapsing, capturing even less solar wind. It is difficult to conceive how solar wind itself could impart much to establishing swarms across the solar system.

Solar sailing in the doldrums

The subject of conjecture for centuries, solar sailing by capturing solar radiation pressure is a process at last developing from model to practice.[21] Marvellous feats of engineering are opening the horizon to new levels of space exploration. Brown cites these advancements as illustrations of the effectiveness of solar radiation pressure in propelling swarms into the outer reaches of the solar system, yet how these state-of-the-art technologies apply to swarms is not explored. Historically, solar sailing by reflective lightsails has been the primary topic of discussion, which Brown relies heavily upon, yet an effective lightsail is extremely difficult to achieve. A lightsail must have a massive area comprised of highly reflective material between 40 and 100 times thinner than a paper sheet.[22] Without this extreme thinness, sails would prove too massive for solar radiation pressure to effectively propel. Swarms would have a much greater area than solar sails to capture solar radiation pressure, yet proportionately would have a much greater mass, making them at best quite ponderous.

An effective lightsail must be perfectly flat due to its reliance on specular reflection,[23] the reflection of light at an equal but mirror angle as the incoming light. Any surface irregularities or absorbance of light would limit the efficiency of specular reflection,[24] hence why lightsails are produced only with the most reflective and planar surfaces possible (figure 4). Swarms, however, would be highly irregular, creating diffuse reflection or scattering of light quite unlike light sails. This diffusive nature means that asteroids have an albedo from 0.02 to 0.5,[25] which itself is low compared to many other materials.[26]

For all their differences, it is difficult to conceive how swarms could match the efficiency of lightsails, yet lightsails themselves are limited. Many researchers point out that lightsails would have insufficient thrust beyond the orbit of Mars,[27] limiting lightsails to the inner solar system.[28] NASA scientists are currently experimenting with diffractive solar sails, not to increase their effective range, but to increase their mobility:

> "Existing reflective solar sail designs are typically very large and very thin, and they are limited by the direction of the sunlight, forcing tradeoffs between power and navigation. Diffractive lightsails would use small gratings embedded in thin films to take advantage of a property of light called diffraction, which causes light to spread out when it passes through a narrow opening. This would allow the spacecraft to make more efficient use of sunlight without sacrificing maneuverability."[29]

These diffusive sails are being developed specifically for investigations of the sun's surface, as they would prove ineffective beyond the inner solar system. As before, however, these diffractive lightsails rely on quite a different realm of light reflection requiring detailed engineering unlike swarms.[30]

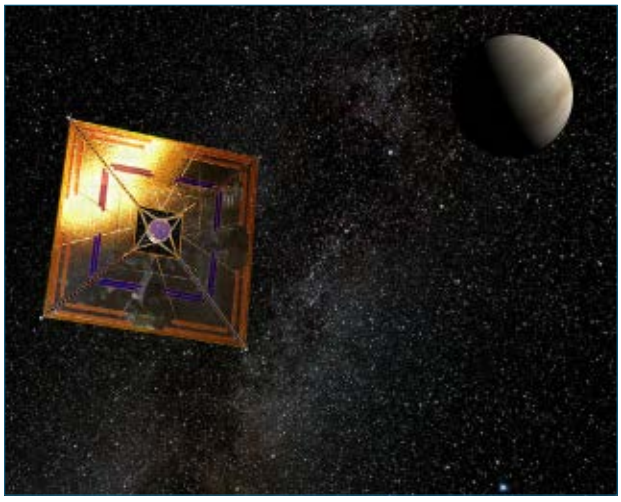

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Figure 4. Based on illustration of cutting-edge lightsail technology, HPT supposes that swarms harnessed momentum imbued by incident photons to propel swarms away from the sun, yet this analogy falls apart. Built lightly and thinly, lightsails are made of the most reflective and planar surfaces possible due to their reliance on specular reflection, near mirror-like reflection of light at the same angle at which it is received. Swarms, however, would diffusively reflect in a scattered pattern, the bane of lightsail performance. As such, it is questionable how lightsails provide an adequate illustration of HPT concepts.

Given the engineering prowess required for producing effective solar sails, HPT must answer how a far less ideal substance utilizing diffusive rather than specular reflection could ever attain a considerable contribution from solar radiation pressure. Could swarms of granite fragments through randomized capture of solar radiation pressure achieve what decades of state-of-the-art engineering and millions of dollars in funding have thus far failed to achieve?

Gas pressure too slight

Releasing water across the solar system, the fountains of the great deep launched from Earth not only granite fragments but also much of the antediluvian subterranean water. The increased particle density within the solar system is believed to aid swarms by applying thrust via temperature and pressure differences on the illuminated and shadowed faces of swarms. How much force could be applied by these temperature variations would depend upon the amount of water released from Earth.

Consider a subterranean water chamber averaging 2.0 km (rounding up Brown's 1.6 km) nearly 6,660 km from Earth's centre, as predicted by HPT.[31] Using concentric shells, the volume of water within that subterranean chamber would equal 1.12×10^{21} kg. Brown states that at least half of Earth's antediluvian water supply was stored within the subterranean

water chamber.[32] As such, total water within the HPT Earth System w_T would be 1.12×10^{21} divided by 50%.[33] The mass of current oceans equalling 1.35×10^{21} kg subtracted from w_T yields $w_a = 8.9 \times 10^{20}$ kg of water available to be released into the solar system. Not all of this would be available for fuelling swarms, however, for Brown speculates that Mars' ocean water was derived from bombarding comets during and soon after the Flood.[34] As such, the mass of Mars' ocean must be removed from the total available water w_a. After subtracting the minimum estimated 6% of Earth's ocean mass,[35] nearly 8.9×10^{20} kg or 2.7×10^{46} particles of water remain for providing thrust to swarms. This amount of water is enough to double the background particle density of 5 particles per cubic cm within a radius of 72 AU.[36] Clearly, this contribution of water would dramatically increase the particle density within the solar system during and immediately following the Flood.

Let us suppose that these water particles were concentrated around Earth to a radius of 6.31×10^5 km or the distance at which Earth's gravity can be deemed 'negligible'. Such a volume (excluding Earth's volume to the atmosphere) would dictate an average particle density of 1.52×10^8 particles/cm^3 or mass density ρ of 4.55×10^{12} kg/m^3. Using this density, we may solve for resulting pressure using the equation:

$$P = \frac{\rho RT}{M}$$

A rearrangement of the equation used to find atmospheric pressure, R is the perfect gas constant, T is the temperature of our gas, M is the molar mass, and P is the resulting pressure. Because a swarm would feel pressure from both the illuminated (high temperature) face and shadowed (low temperature) face, high temperature would provide a driving pressure P_{drive} while lower temperature would repel with a resisting P_{resist}. Using the extremes of temperatures experienced on Mars as a proxy for high ($T_{drive} = 308$ K) and low ($T_{drive} = 210$ K) temperatures, we find:

$$P_{drive} = \frac{\rho RT_{drive}}{M} = 6.47 \times 10^{-7} Pa$$

$$P_{resist} = \frac{\rho RT_{resist}}{M} = 4.41 \times 10^{-7} Pa$$

The net pressure acting from the sun, then, is the difference between P_{drive} and P_{resist} or $P_{total} = 2.06 \times 10^{-7}$ Pa. Using the conditions and approach enumerated on the analysis of solar wind acting on a Ceres-like swarm, this pressure would require 33,000 years. Though only a fraction of the time required for solar wind alone, this timeline remains far too great for the biblical chronology.

That said, a higher net pressure can be achieved under increased particle densities. Assuming a timeline of 5,000 years to 'reverse engineer' the particle density, we find the required particle density to drive a Ceres-like swarm into Ceres' orbit to approximate 6.64×10^{15} particles/cm^3 or seven orders of magnitude greater than that used in the preceding calculations. Such a particle density, however, would be contained within a nested sphere around the earth of radius 0.066 AU. Though 27 times greater than the distance between Earth and the moon, it is a mere 2.6% of the distance between the orbits of Earth and Mars. Such a great density close to Earth seems unlikely to last for long, as Earth itself, at a velocity of 29.9 km/s, would orbit beyond this sphere in a fraction of a single day. Furthermore, this sphere would quickly diffuse, drawn to the lower densities beyond and the driving effect of solar wind sweeping water molecules further from the sun. As demonstrated above, such diffusion would only decrease the net pressure and increase the associated travel time. As if this were not enough, these calculations presume pressure was added continuously, building acceleration and velocity gradationally over time on a swarm's journey to the asteroid belt, yet such a density would provide this pressure for only 2.6% of that journey. Even using this generalized approach maximized in HPT's favour, gas pressure appears to be far too small to successfully power swarms along their journey.

Atmospheres around swarms only muddy the water.

With comets measuring over 30% water by mass[37] and an increasing number of TNOs showing evidence for surface composition well exceeding 20% water by mass,[38] HPT requires that the subterranean water released along with granite fragments did not remain in a single place, as assumed in the previous section, but created atmospheres around swarms that eventually coalesced into the icy components of comets, asteroids, and TNOs. It is important to realize, however, that should TNOs be comprised of only 1% water by mass,[39] the water available for swarms would account for only half of the water required to produce TNOs.

Notwithstanding, swarms guiding their own atmospheres would allow thrust to be constantly applied to the swarm along its entire journey rather than receiving thrust for an initial portion as required by the previous scenario. That said, this would severely undercut the available pressure applied to swarms, as their atmospheres, considered individually, would be far less dense than the collective atmospheres agglomerated in a single sphere. The smaller density would apply less force than our best-case scenario above, indicating that even with swarms guiding their own atmospheres along their entire journey, this constant pressure would be far too negligible. The applied pressures as considered above could

scarcely be expected to move a Ceres-like object 1.77 AU in less than dozens of thousands of years.

Such a scenario, however, is itself unlikely. The very objects allegedly once swarms rarely have the mass required to maintain their own atmosphere today at even extreme distances from the sun, yet HPT requires those same objects once had atmospheres propelling them to their current locations. Solar wind should have stripped swarms of their atmospheres, removing the necessary thrust. Negative ionization from solar wind would aid gas particles in repelling each other. The very mechanism for applying thrust to swarms by temperature differences would slowly diffuse atmospheres, as higher temperatures would add momentum from particles helping them to not only add thrust to the swarms but, in some cases, *to escape them*. With particle motion seemingly 'random' in direction, little requires particles to always collide with the swarm, and once their motion is redirected after collision, to retain them within that atmosphere. HPT must explain how these atmospheres could be held by swarms for the timelines required and if such atmospheres could have applied the required force for those journeys.

Discussion

Considered individually, each passive mechanism contributes too little energy to be significant within the required timeline. Solar sailing remains difficult to model for swarms despite the serious questions implying its irrelevance for driving swarms. Likewise, solar wind and gas pressure are too severely underwhelming even when combined. Requiring a timescale in the hundreds of thousands of years, solar wind contributes only a fraction of the force supplied by the best-case scenario of gas pressure, making it negligible in comparison to force arising from gas pressure. With the other sources paling in comparison, gas pressure is left to shoulder the burden alone, yet it is far too slight to carry swarms along their journey.

These questions become graver when considering TNOs, which would have travelled another 28–68 AU further than our hypothetical Ceres-like swarm (figure 5). For this hypothetical scenario for a swarm the mass of Pluto, we set the swarm radius to 10,000 km, nearly as great as Brown's maximum[40] estimated 12,010 km-radius for the ancestral Pluto swarm.[41] Such a swarm would capture nearly the same amount of force to move a mass nearly two orders of magnitude greater. Indeed, assuming the best-case gas pressure scenario considered above, such a swarm would capture only 44.2% more force to move a swarm totalling 1,400% of the mass over a distance 14 times greater within the same timeline. This would radically undercut the applied acceleration on the swarm, dramatically lengthening the timeline from 33,000 years for the Ceres swarm to an order of magnitude greater. Such a scale poses serious questions for the HPT astronomical submodel. Given that these passive solar-driven processes prove effective only on the scale of tens of thousands of years, how could this be considered an adequate means of supplying the energy lacking by many orders of magnitude?

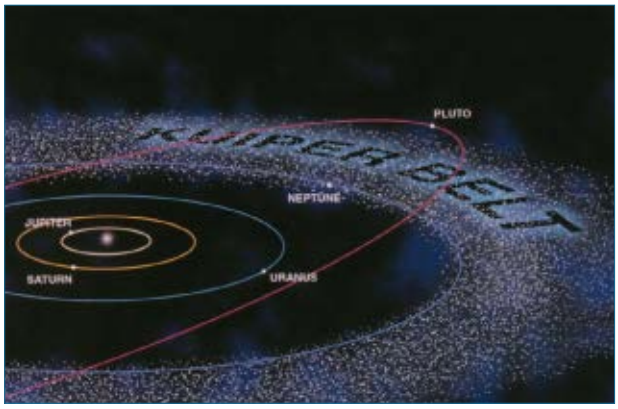

Image: NASA / Public Domain

Figure 5. With the radiometer effect requiring tens of thousands of years to reach a mere 3 AUs from the sun, consider the timescale required to reach the Kuiper Belt and other nearby trans-Neptunian Objects 30 to 70 AUs from the sun. At best, the radiometer effect would be negligible within the timescale allotted by Scripture, making it an inadequate source to supplement HPT's lacking energy budget.

Conclusions

With the insufficiency of its energy budget, HPT requires passive solar-driven forces to propel swarms into the eventual orbits of comets, asteroids, and trans-Neptunian Objects, yet the accumulation of those passive forces is too negligible over short timescales. The radiometer effect, comprised of solar wind, solar radiation pressure, and temperature-driven gas pressure variations, appears too slight to significantly alter the positions of swarms once placed beyond Earth's influence.

Though drawing upon the illustration of solar lightsails, solar radiation pressure poses an intriguing yet speculative energy source. Derived by harnessing specular reflection, rather than diffusive reflection like asteroids today, solar lightsails are a questionable illustration of solar radiation pressure on swarms, which would furthermore be proportionally more massive than their corresponding areas for capturing that force. Likewise, the contributions of solar wind and temperature-driven gas pressure are quantifiably miniscule, requiring upward of tens of thousands of years to propel a Ceres-like swarm into Ceres' current orbit. Indeed, these forces cannot offer significant alteration of swarms' positions throughout the solar system during the timescale allotted by Scripture.

These challenges raise underlying questions of the HPT concept. With the radiometer effect negligible within biblical timelines, the placement of swarms into their current orbits as comets, asteroids, and TNOs must rely solely on the energy available within the antediluvian HPT Earth System, yet this energy supply is orders of magnitude too minor to complete the work required.[9] As such, HPT lacks a satisfactory energy budget to explain the removal of crustal mass from Earth to form the solar system's small bodies. With the insufficiency of HPT's astronomical submodel, how might other key aspects of HPT's grand narrative of Earth's surface reconstruction (e.g. mass balance) be challenged?

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32. Brown, ref. 6, p. 477.
33. We divide by 50% because, per Brown, ref. 6, p. 477, at least 50% of the water within the HPT Earth System was stored within the subterranean water. Dividing by this minimum value of 50% maximizes the mass of water available to release into the solar system.
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37. Brown commonly cites the figure 38% water by mass. See Brown, ref. 6, p. 122.
38. Fernández-Valenzuela, E., Pinilla-Alonso, N., Stansberry, J., Emery, J.P., Perkins, W., Van Laerhoven, C., Gladman, B.J., Fraser, W., Cruikshank, D., Lellouch, E., Compositional Study of Trans-Neptunian Objects at $\lambda > 2.2$ µm, *The Planetary Science J.* **2**(10):1–34, 2021.
39. Given that TNOs total to an estimated 0.1–0.2 Earth mass, as calculated by Shulz, R., Trans-Neptunian objects, *The Astronomy and Astrophysics Review* **11**:1–31, 2002, this requires a minimum of 1.79×10^{21} kg of water or twice that available.
40. Brown determined this value as the maximum radius a swarm of Pluto's mass could maintain while being more gravitationally attracted to each other than to the sun at a distance of 1 AU. Because the swarm could not retain its integrity with a greater radius at that proximity to the sun and would only collapse as the swarm drifted from the sun, 12,010 km would be the maximum hypothetical radius.
41. Pluto averages an orbital radius of 39.5 AU.

Drawing from over a decade of study to his credit, ***Edward A. Isaacs*** *is a keen student of the sciences, focusing on the geological processes of the Genesis Flood and ensuing Ice Age. Edward has a heart for serving the Lord and uses his degrees in the geosciences and engineering to educate others as both a Research Associate at Genesis Apologetics and an ambassador of Logos Research Associates.*

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